DRAFT REPORT

IN-DELTA STORAGE PROGRAM RISK ANALYSIS

Prepared for

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1.1 PURPOSE AND SCOPE

The Department of Water Resources (DWR) is conducting feasibility-level engineering and environmental studies under the Integrated Storage Investigations Program. As part of the project evaluations, DWR is evaluating the technical feasibility and conducting engineering investigation for the In-Delta Storage (IDS) Program. The engineering investigation will aim at developing solutions to enhance project reliability through improved embankment design and consolidation of inlet and outlet structures.

As part of this feasibility study, DWR requested that URS Corporation (URS) undertake a detailed risk analysis and integrate the physical design with a desirable level of protection through seismic, flooding, operational, environmental, and economic analyses. Other objectives were to recommend a desirable level of protection and an appropriate factor of safety for the project.

The specific scope of work under this task order was to evaluate the consequences of failure of the existing levees and In-Delta Re-engineered project (embankment and integrated facilities) under all loading events (operational, seismic, and flooding) and estimate the loss-of-life risk and economic losses through uncontrolled releases. The risk analysis was to be conducted in accordance with the general guidelines of the USBR risk analysis presented in a handout distributed during a scoping meeting on July 18, 2002 among DWR, USBR, and URS staff. These guidelines are also described in a U.S. Bureau of Reclamation document (USBR, 1999). Although the general guidelines in the handout were used to define the overall risk for this project, the specific methods used to estimate failure probabilities differed from the USBR methods as noted in Section 1.2 below. Furthermore, economic impacts were incorporated in this risk analysis in order to provide input for cost-benefit analysis in accordance with the scope of work.

The main objective of this task order was to evaluate the risk of failure of the existing levees and In-Delta Re-engineered project for Webb Tract and Bacon Island. Two project alternatives – Rock Berm and Bench – were to be analyzed at each of the two project islands. Figure 1 shows the cross sections of these two alternatives. The results of the analysis were to be used to evaluate the expected project performance relative to the “no action” alternative (i.e., existing levee condition).

This report updates a previous URS risk analysis report submitted to DWR in May 2003. The specific updates to be incorporated in this report were:

1. Include impacts to certain infrastructure facilities that were not covered in the original risk analysis. These facilities include the EBMUD Mokelumne Aqueducts, PG&E gas pipelines, BNSF railroad lines, and Kinder Morgan pipeline. Damage to these facilities and resulting direct economic losses were to be estimated as a result of an embankment breach at Bacon Island.
2. Include new information available as a result of the June 3, 2004, Middle River levee breach at Upper Jones Tract in the Sacramento-San Joaquin Delta. The updated analysis was to consider levee breach and scour hole dimensions; cost of levee repairs; cost to restore the Jones Tract Islands to suitable farming conditions; flood damages on Jones Tract Islands

including damage to infrastructure; and impacts to state and federal project water supplies and Delta water quality.

1.2 ASSUMPTIONS AND LIMITATIONS

The following is a list of assumptions and limitations used to evaluate probabilities and consequences of failure and to calculate the project risk:

- Probability of simultaneous occurrence of two major events (flooding and earthquake for this analysis) is negligible. This is a common assumption in risk analysis.
- The reservoir would operate at or near full level (elevation +4ft.) during the months of April through June and at or near empty level (elevation –15ft.) during the months of July through March (URS, 2004b).
- Probability of more than two simultaneous breaches of the embankment within each island due to flooding or earthquake is negligible.
- Probability of more than one simultaneous breach of the embankment within each island due to operational loading is negligible.
- Probability of failure of the levee on each neighboring island given that the embankment fails during flooding or earthquake is 100%. That is, if an earthquake or a flood causes the embankment to fail, it would also cause the levees on neighboring islands to fail. This is a reasonable assumption because the embankment would be an engineered project designed to have a higher reliability of performance under seismic and flood loading. In contrast, most of the existing levees are not engineered structures and hence would be much more vulnerable to seismic and flooding events. Thus, if an earthquake or flood were strong enough to cause the engineered embankment to fail, it would cause the levees to fail as well.
- The simultaneous failure of the project embankment as well as the existing levees would cause system-wide hydraulic changes in the Delta. As stated above, if an earthquake or flood causes the failure of the embankment, it is also assumed to cause the failure of the levees on neighboring islands. In such a scenario, the overall impact of the system-wide hydraulic changes to water quality could be substantial. However, the incremental impact of the embankment failure to water quality by itself (for example, increased salinity) would not be significant. This is a reasonable assumption because the volume of water that would be drawn from the slough into the reservoir, or released from the reservoir into the slough, would be only a small portion of the total volume of water that would be drawn into all the other islands. Therefore, the impact to Delta water quality is analyzed only under an operational failure, but not under a failure due to flood or earthquake loading.
- Given a failure of the embankment due to operational loading and an outward breach that floods the slough, there is a finite probability that a levee on a neighboring island would fail due to flood wave impact. This probability of levee failure depends on the slough width (with higher probabilities for narrower sloughs) and also on the probability of successful flood fighting measures on the neighboring islands.
- During a flooding event, relatively little boating activity is assumed to be present in the slough.

- Only direct costs and benefits are included in the economic analysis. Indirect and induced local economic effects (the "ripple" effects) are not considered.
- Only readily available and published information is used to estimate economic losses from a failure of the embankment or a levee on a neighboring island (no field surveys were conducted). Where necessary, professional judgment is used to supplement available information to estimate economic losses.
- Consistent with the agreed upon scope of the project, the failure probabilities in specified failure modes were estimated based on well-documented results of prior studies and engineering judgment. The prior studies used in this analysis are properly referenced. The scope did not include developing detailed event trees for each failure mode as described in USBR guidelines (USBR, 1999). In this specific respect, the standard USBR method of event trees, which employs a series of subjective probabilities to estimate the overall failure probability, was not used. However, the estimated failure probabilities are based on well-documented engineering studies for the project site. For example, the probability of failure due to seismic loading was based on a deformation analysis (URS, 2003a), which integrates cross-section geometry and the agreed upon material properties. This provided an objective method of analyzing embankment deformation and estimating the probability of failure.

Following basic principles of risk analysis, and consistent with the overview provided in the handout of July 18, 2002, distributed among DWR, USBR, and URS staff, risk for this project was defined as the product of the probability of a loading event, times the probability of system failure when subjected to the loading event, times the consequences of system failure.

An “event tree” model was used to represent the chronological sequence of events from the occurrence of a loading event to the embankment failure to consequences of failure. Figure 2 shows a schematic representation of the event tree model that was used to analyze the risk of embankment failure. This model was applied to each of the two reservoir islands – Webb Tract and Bacon Island. The main steps in implementing the model for each reservoir island were as follows:

- Identify alternative projects for the project embankment.
- Identify loading events.
- Characterize alternative load levels of each loading event.
- Characterize alternative operational scenarios.
- Evaluate the probability of a breach for each combination of loading event, load level, and operational scenario.
- Evaluate probabilities of alternative breach scenarios given the occurrence of a breach.
- Evaluate the expected consequences of each breach scenario.
- Integrate the information from the previous steps to calculate the risk of failure.

A brief description of each step follows.

2.1 IDENTIFY ALTERNATIVE PROJECTS FOR THE RESERVOIR ISLAND EMBANKMENTS

The set of alternative engineered projects included the “no-action” alternative (i.e., the existing levee), the re-engineered project as currently defined, and any project variations that were identified based on the engineering evaluations conducted in the other task orders in this study.

2.2 IDENTIFY LOADING EVENTS

Three types of loading events were analyzed to evaluate the risk of embankment failure – flooding, seismic, and operational.

2.3 CHARACTERIZE ALTERNATIVE LOAD LEVELS OF EACH LOADING EVENT

The load levels for flooding and seismic events were defined in terms of intervals of the return period. For each interval of the return period, a representative return period was defined for use in the subsequent steps. For operational loading events, only a single load level (corresponding to the critical condition expected to occur each year) was defined. Table 1 shows the different load levels for flooding, seismic, and operational events, the intervals of the return period for each load level, and the representative return period for each interval.

2.4 CHARACTERIZE ALTERNATIVE OPERATIONAL SCENARIOS

The reservoirs would operate at various levels during a typical year. For risk analysis, two critical stages of the reservoir levels were considered – reservoir full (elevation +4ft.) and reservoir empty (elevation –15ft.). The reservoir was assumed to be full during the months of April through June and empty during July through March. For a failure due to operational loading, the period of July through March was further sub-divided into two intervals corresponding to the winter and summer/fall months because the water quality impact of a reservoir breach during these two intervals would be different. During the winter months of December through March, the Delta system would receive high flows of fresh water thus mitigating the impact of increased salinity caused by an inward breach of the reservoir. During the months of July through November, the flow of fresh water would be low, which may cause migration of salinity into the Delta if an inward breach were to occur.

The slough water levels vary during daily tide cycles. Each reservoir level was combined with a daily tide cycle that would produce a critical condition. The full reservoir level was combined with a low tide cycle (slough water level at elevation -1ft.) and empty reservoir level was combined with a high tide cycle (slough water level at elevation +3.5ft.).

During a flooding event, which is likely to occur only during the winter months of December through March, the reservoir would be empty (elevation –15ft.) and the slough water level would be high (elevation from +6.6ft. to +8ft.).

Table 2 defines the alternative operational scenarios for each loading event in terms of the reservoir level, the months of annual operation in each level, and the assumed slough water level.

2.5 EVALUATE THE PROBABILITY OF A BREACH GIVEN LOADING EVENT, LOAD LEVEL, AND OPERATIONAL SCENARIO

For each combination of the loading event, load level, and operational event, the probability of a breach (leading to an uncontrolled release of water) was evaluated for each of the two project alternatives – Rock Berm and Bench, and for the existing levee. The results of prior studies and engineering judgment were used to evaluate the breach probabilities. The failure modes included overtopping and piping/internal erosion due to flooding, slope instability and liquefaction due to a seismic event, and slope failure and piping/internal erosion under operational loading.

Probabilities of a breach due to seismic events and operational loading were adopted from other URS reports (URS, 2003a; URS, 2003b). The probability of failure of the existing levees on the project islands was based on the current geometry and elevations. Based on current maintenance practices, it was assumed that the levees would be monitored periodically for any on-going subsidence and appropriate remedial measures (such as raising the top elevation) would be taken to compensate for adverse effects of subsidence.

The probability of overtopping due to flooding was estimated based on the expected flood level for a given flood event and the wave height. The analysis of flood levels and wave heights is described in the URS flooding analysis report (URS, 2003c). The combined water elevation from the flood level and wave height was compared to the crest elevation to assess whether overtopping would occur. For Webb Tract, the maximum flood levels for 50-, 100-, and 300-year flood events were estimated to be 6.8, 7.1, and 7.2 feet, respectively, and the wind wave runup plus setup for the re-engineered embankment was estimated to range from 0.6 to 1.8 feet. For

Bacon Island, the maximum flood level was estimated to be 6.9, 7.3, and 7.5 feet for the 50-, 100-, and 300– year flood events, respectively, and the wind wave runup plus setup for the re-engineered embankment was estimated to range from 0.6 to 1.4 feet. The maximum crest elevation for the re-engineered embankments is 10.3 feet (URS, 2003c).

Based on these data, the probability of overtopping was estimated for the intervals of flood return periods shown in Table 1. The probability was estimated to be 0 for 1- to 10-year and 10- to 150-year flood events. For a 150- to 450-year flood event, the probability of overtopping would range from 0 for up to 300-year flood events to 100% for a 300+ year flood event. For this analysis, an average value of 50% was used for the interval of 150- to 450-year flood event. The probability of overtopping would be 100% for 450-year plus flood events.

The probability of piping/internal erosion failure due to flooding was estimated using the information in a URS report (URS, 2003b). For a 1- to 10-year flood event, the probability of piping/internal erosion was included in the operational loading. This probability was estimated to be about 0.014% for an inward breach and about 0.003% for an outward breach. For a 10 to 150-year flood event, the probability of piping/internal erosion was estimated to be 0.0013%. For a 150- to 450-year flood event, the probability of piping/internal erosion was estimated to 0.0035%. The probabilities of overtopping and piping/internal erosion under each flood event were combined to obtain the total probability of failure for that event. The data were similar for both reservoir islands and the same failure probabilities were assumed for both islands.

For the existing levees at Webb Tract and Bacon Island, the wind wave runup plus setup was assessed to be about 2 feet. The crest of the existing levee was assumed to be at elevation 8 ft., on average, based on topographic maps (URS, 2003b). In this case, the probability of overtopping was assessed to be 0 for up to 10-year flood events. For 10- to 150-year flood events, the probability of overtopping would range from 0 to 100%; for this analysis, an average value of 50% was used. The incremental probability of piping/internal erosion under 100-year flooding was calculated by assuming the same proportional increase from the annual probability of failure under operational loading as that for an engineered alternative. The probability of overtopping would be 100% for 150-year plus flood events.

Table 10 summarizes the probabilities of an embankment breach at each project island under different loading events.

2.6 EVALUATE PROBABILITIES OF ALTERNATIVE BREACH SCENARIOS GIVEN THE OCCURRENCE OF A BREACH

For flooding and seismic events, two breach scenarios were analyzed – one breach occurring or two breaches occurring simultaneously within the same island or tract. As stated in Section 1.2, the probability of more than two breaches occurring simultaneously under seismic and flooding events was considered to be negligible. The (conditional) probabilities of alternative breach scenarios given the occurrence of at least one breach were estimated using historic data and engineering judgment. Historically, levee failures during flooding have occurred, but more than one breach on a given island have not been observed. Therefore, the occurrence of two breaches of a levee in a single event was judged to be unlikely, particularly for low load levels.

For up to 450-year flood events, the probability of two breaches was considered to be unlikely. For these events, the (conditional) probability of a single breach was estimated to be 100% and the probability of two breaches was assumed to be zero. For a 1,000-year plus flood event, the two breach scenarios were considered to be equally likely and a probability of 50% was assigned to each scenario. For a 450- to 1,000-year flood event, the single-breach scenario was considered to be three times more likely than the two-breach scenario. Therefore, probabilities of 75% and 25% were assigned to the single- and double-breach scenarios, respectively.

Similar rationale was used to estimate the probabilities of breach scenarios under seismic loading. For moderate seismic loading (return period less than 10 years), the probability of two breaches was considered to be small (about 5%). On the other hand, for a seismic event with a return period of 2,500 years, the events of one breach and two breaches were considered to be about equally likely. For intermediate seismic events, the probability of two breaches was adjusted between the boundaries.

Under operational loading, only the single-breach scenario was analyzed. To model the spatial distribution of system failure, each project embankment was divided into individual reaches. Each reach was the section of the project embankment that adjoins a neighboring island such that a failure of the reach would directly impact the neighboring island. The probability of a breach on each reach was estimated based on the proportion of the embankment perimeter assessed for each reach. For example, the reach of the Webb Tract embankment in front of the Bradford Island was estimated to be 20% of the total perimeter of the embankment. Therefore, a probability of 20% was assigned to the breach scenario for this reach. A representative location was assumed for an embankment breach within each reach. Table 11 summarizes the probabilities of breach scenarios under different loading events.

If the breach is outward, the levee on the island adjoining the breach may also fail. The probability of failure of the levee depends on the width of the slough separating the two islands and on the success of any flood fighting measures that may be undertaken. The greater the width of the slough separating the two islands, the less severe would be the threat to the integrity of the neighboring island levee and the probability of a levee breach at the neighboring island would be less. Four categories of slough width were considered: narrow (less than or equal to 1,000 feet), medium (1,000 feet to 2,000 feet), wide (2,000 feet to 3,000 feet), and very wide (greater than 3,000 feet).

The breach analysis performed by URS (URS, 2003) estimated peak water velocities at the edge of the slough following an outward breach for the four categories of slough width. For example, under a head differential of 5 feet, the estimated velocity was 6.2 ft/sec for a wide slough. The critical velocity that would initiate a breach of the levee on an existing island was judged to be 8 to 10 ft/sec, with an average of 9 ft/sec. Because of the uncertainty in the model and input data used in estimating velocities, the estimated velocity would also be uncertain. Based on professional judgment, the coefficient of variation for the estimated velocity was assessed to be 25% (i.e., the standard deviation of the velocity was assumed to be 25% of the estimated velocity). Because the actual velocity could be equally likely to be higher or lower than the estimated velocity, a normal probability distribution, which is symmetric about the estimated velocity, was assumed for the velocity.

Using these assumptions, the probability of a levee failure caused by a breach of the reservoir island was calculated to be about 5% for a wide slough. For a wide slough, a longer warning period would be available to deploy flood-fighting measures on the neighboring island. For this case, the probability of successful flood fighting was assessed to be 50% based on professional judgment. Thus, the probability of a levee failure on a neighboring island separated by a wide slough from the project island and triggered by an outward breach of the project island was calculated to be (0.05 x 0.5 =) 0.025. Probabilities for other slough widths were assessed similarly and are shown in Table 13. These probabilities and other input parameters are summarized in Section 5.

A breach on the southern portion of the embankment on Bacon Island would create a potential to cause a failure of other infrastructure facilities, including the East Bay Municipal Utility District (EBMUD) Mokelumne Aqueducts, Kinder Morgan pipeline, and BNSF railroad embankment and tracks. The probability of failure of each facility at risk was assessed using appropriate hydraulic analysis, data from past failures, and professional judgment. Furthermore, Pacific Gas and Electric (PG&E) gas pipelines pass through Bacon Island. These pipelines are also at risk from a breach on a relevant reach of the embankment on Bacon Island. The assessment of the failure probabilities for these facilities is described in Section 3. A map showing the various infrastructure facilities at risk near Bacon Island is included in Figure 3.

2.7 EVALUATE THE EXPECTED CONSEQUENCES OF EACH BREACH SCENARIO

The economic losses resulting from an inward and outward breach of the project embankment and the flooding of neighboring islands were evaluated. Only the direct economic losses were evaluated; no indirect losses (“ripple effects”) were considered. For example, in the event of a failure of the PG&E gas pipeline, the analysis included direct loss of revenue to PG&E, but did not include any economic impacts to PG&E customers due to reduced gas supply. The various consequences of concern are evaluated in Section 3.

One consequence of concern is the flooding of a neighboring island caused by a breach of the project embankment that, in turn, triggers a breach of the levee on the neighboring island. On June 3, 2004, a levee breach occurred on the Upper Jones Tract that resulted in flooding of Upper and Lower Jones Tracts, and caused substantial damage and economic losses. Because the risk analysis in this study incorporates this type of a failure scenario, the data from the June 3, 2004 event are useful to validate, and revise if necessary, the assumptions made in estimating economic losses from any future flooding of the Jones Tract islands, as well as other neighboring islands in the study area. Therefore, DWR and URS staff reviewed and compiled information from the levee breach and its impacts. Appendix A provides data summary and photographs for this levee breach event. The relevance and use of this information to estimate various parameters of the present risk analysis are noted where applicable in Section 3.

2.8 INTEGRATE THE INFORMATION FROM THE PREVIOUS STEPS

This step involves integrating the estimated probabilities and consequences of failure from the previous steps to generate the risk profile of the engineered project. The risk was expressed in terms of the expected life dollar losses during an assumed project life of 50 years.

This section discusses the consequences of failure of the project embankments. The consequences of failure are evaluated for both inward and outward breach scenarios as discussed in Sections 3.1 and 3.2, respectively. These consequences include (1) emergency response; (2) embankment repair; (3) damage to equipment; (4) impacts to fish, water quality and supply, gas pipelines, railroads, aqueducts, and other infrastructure; and (5) loss of life. The consequences of flooding of neighboring islands are addressed in Section 3.3 and include emergency response and repair of damage to levees, buildings and infrastructure and impacts to agricultural resources, natural habitats, water quality and supply, and infrastructure. Estimated costs of these consequences are presented in the sections below.

3.1 CONSEQUENCES OF INWARD BREACH OF PROJECT EMBANKMENT

The economic losses/costs associated with the following consequences of an inward breach of the project embankment were evaluated. The dollar values associated with these economic losses/costs are summarized in Table 3.

3.1.1 Emergency Response

The data from the Jones Tract failure of June 3, 2004 was used to estimate the emergency response cost following a breach of the project embankment without a failure of a neighboring island. The emergency response cost for the Jones Tract event (excluding the cost of pumping out water from the Jones Tracts) was about $25 million (based on information in Appendix A). This response required large-scale actions to protect the entire perimeter of Upper and Lower Jones Tracts. If only the project embankment were to breach, the emergency response cost would be much less, which was assumed to be $2.5 million.

3.1.2 Embankment Repair

In the May 2003 risk analysis report (URS, 2003e), the cost of embankment repair was estimated based on an assumed breach length, the quantity of new material that would have to be placed, and unit construction cost. However, the Jones Tract failure of June 3, 2004 provided real data on levee breach repair cost under emergency conditions. The cost data were used in this risk analysis as discussed below.

Construction of the closure of the breach in a reservoir embankment would be similar to that used to close the breach in the Jones Tract levee. Essentially, initial closure is achieved by placing rock materials through water. A 2-foot thick riprap layer would be placed on the slough-side of the embankment. A layer of bedding (well-graded granular material from 6-inch rock to sand and silt sizes) would underlie the riprap layer. Soil materials would be used in the remainder of the embankment (reservoir side). The cost of this repair work for the Jones Tract levee failure amounted to about $10.3 million[1] for a 400-foot-wide breach. To close a 1000-foot wide breach assumed for the risk analysis, the repair cost would be roughly 2.5 times (1000 ft / 400 ft) the cost to close a 400-foot wide breach, or about $25.8 million.

[1] Appendix A indicates a cost of $8.6 million to repair the breach in the Jones Tract levee. Subsequent information provided by DWR indicates that the total cost was about $10.3 million, which included furnishing and placing fill materials for a seepage reduction blanket on the levee.

After the breach has been closed, construction to re-establish the embankment slopes in the interior (reservoir side) of the island, shown on Figure 1, can proceed in the dry using conventional earthmoving operations. Based on the costs reported in the Earthwork Construction Cost Estimate (URS, 2003d), the costs to re-establish the interior embankments (1000 foot-wide segment) are estimated to be an additional $2 million for the Rock Berm Option and $2.5 million for the Bench Option. Therefore, the total repair cost would be about $28 million for either option.

3.1.3 Damage to Equipment

The damage to the interceptor wells and integrated facilities was assessed under each breach scenario and the cost to repair the damage and restore functionality was estimated as described below. Failure of the interceptor wells without a breach (i.e., due to malfunctioning) was not analyzed. This is because the embankment would have many interceptor wells and several interceptor wells must fail before a significant increase in the groundwater table at a neighboring island would occur thereby causing crop losses. The probability of simultaneous failure of multiple wells due to malfunctioning was judged to be negligible.

The interceptor wells were assumed to be placed on the embankment at 200 feet spacing. For an assumed breach width of 1,000 feet, five interceptor wells would be impacted. Each impacted well would have to be replaced. The construction cost of a well was estimated to be $30,000 (URS, 2003d). Allowing for a contingency for an emergency replacement, the cost of replacing each well was assumed to be $40,000 in this analysis.

Two integrated facilities were assumed for each reservoir island and each facility was assumed to be 1,000 feet wide. If the mid-point of a breach were to be within 500 feet from either end of the integrated facility, it was assumed that the integrated facility would be impacted. Thus, if a breach were to occur such that its mid-point is over a distance of 2,000 feet centered on the integrated facility, the facility would be impacted. The probability of a breach over a distance of 2,000 feet was calculated as (2,000/perimeter of the island). For two integrated facilities, this probability is equal to (2,000 + 2,000)/perimeter. Because the integrated facility would be founded on piles, there is an even chance that it would withstand the impact of an embankment breach without significant damage. That is, the probability of significant damage to the integrated facility when subjected to an embankment breach would be 50%. The probability of significant damage to an integrated facility then would be (4,000/perimeter) x 0.5. Thus, for example, the probability of significant damage to an integrated facility at the Webb Tract is (4,000/68,247) x 0.5 = 0.029. The construction cost of an integrated facility was estimated to be about $50 million (URS/CH2M Hill, 2003). The cost of repairing such a facility for both Rock Berm and Bench alternatives was estimated to be 1% of the construction cost, 0.01 x $50 million = $500,000. These repair costs were also used for Bacon Island for the Rock Berm and Bench alternatives.

3.1.4 Impact to Fish

Fish may be trapped inside the reservoir once the breach is repaired. Although costs were not incurred as a result of the 2004 Jones Tract failure, a cost for seining and transporting fish has been included in this study. The cost of seining the fish and transporting fish back into the slough was estimated to be about $10,000.

3.1.5 Impact to Water Quality and Water Supply

The flow of the Delta water into the reservoir would draw the marine water upstream and could increase the salinity of the Delta water at the pumping stations for Contra Costa Water District (CCWD) and also possibly for the State Water Project (SWP) and Central Valley Project (CVP). This scenario of increased salinity at the pumping stations is analyzed only during the season of low fresh water flows (July through November). During the high fresh water flows (December through March), the increased salinity zone is unlikely to reach the pumping stations.

Because the water treatment equipment is not designed to process high-salinity water, the Delta water at the affected intakes may not be pumped during the period of high salinity. The duration of pumping interruption was assumed to be four days based on discussion with CCWD and the experience with the 1972 Brannan Island failure that caused elevated concentrations of chlorides at Rock Slough. It is worth noting that the Jones Tract levee break and subsequent flooding did not cause adverse impact to water quality at CCWD intakes and no pumping interruption or additional treatment costs were incurred due to the time of year of the failure and operation restrictions. The assumption of four days of CCWD pumping interruption under this scenario is conservative. The corresponding loss of water supply would have to be made up from emergency sources. The various water user agencies that depend on the Delta water supply have emergency water storage facilities that could be used in case of a failure of the Delta water supply system. After the normal operating conditions are restored, the water taken out of the emergency source would have to be replenished. The cost of acquiring and pumping the make-up water was estimated under this scenario, as described below.

We estimated that CCWD would have to use about 25,000 acre-feet of water from the emergency storage in the Los Vaqueros Reservoir during the period of high salinity. Interruption of water supply would also occur for the SWP and CVP users. Using available data for the SWP and CVP pumping operations and assuming four days of interruption, the volume of water that would be lost to SWP and CVP during an inward breach was estimated to be 50,000 acre-feet. Thus, the total volume of water that would have to be made up following an inward breach during the period of low fresh water flows would be 75,000 acre-feet. Based on recent experience, in case of an interruption of Delta water supply, the estimated value of acquiring and pumping the make-up water is $210 per acre-foot (DWR, 2004).

As stated in Sections 1.2 and 2.1.4, the impact to water quality was analyzed only when the breach would be caused under operational loading and there was low fresh water flow. If the embankment were to fail under a seismic or flooding event, many of the existing levees, which are more vulnerable, are also likely to fail under the same event. This scenario would cause system-wide hydraulic changes in the Delta. Although the impact to water quality of such a scenario could be substantial, the incremental impact due to the reservoir breach alone would be relatively small. An additional factor when analyzing a breach under a flooding event is that there would be a large amount of fresh floodwater that would push the zone of salinity-impacted area downstream.

3.1.6 Impact to PG&E Gas Pipelines

Two PG&E gas pipelines cross Bacon Island at the juncture of Mildred Island on the eastern side of Bacon Island. Only the northern pipeline is active, while the southern pipeline is maintained as a possible backup. The northern pipeline also crosses Bacon Island at the western end of Palm Tract.

The foundation of the pipeline crossings under the Bacon Island reservoir embankments would require special treatment to minimize the potential for settlement of the pipelines due to the increased embankment loading. Such treatment may include excavation of soft or loose soils and replacement with compacted earthfill and/or in situ ground treatment such as compaction grouting, jet grouting, or deep soil mixing with cement.

The probability and consequences of a failure of the PG&E gas pipelines crossing Bacon Island were estimated if such a failure were to occur due to an inward breach of the project embankment at Bacon Island. It is recognized that the pipeline would be under hydrostatic loading from the reservoir, which would need to be addressed during final design. Consequences of a failure of PG&E pipelines under normal operation (without a breach of the project embankment) were not included in the risk analysis. For example, if the PG&E pipeline were to fail under normal operation, the cost of repair could be higher because of being under several feet of water. This incremental cost was not considered in this risk analysis because it is not related to the risk of a failure of the project embankment, and hence should be considered to be a part of the normal operation cost.

An inward breach at these locations could scour the bottom of Bacon Island and cause a failure of the gas pipelines. Past levee failures under flood conditions appear to have caused large scours. A review of an aerial photograph of the study area suggested that the dimensions of a major scour following an inward breach could be about 1,700 feet long, 600 feet wide, and 50 feet deep. Because the gas pipelines would be within such a zone of impact, it was assumed that the gas pipelines would fail if an inward breach were to occur within 600 feet along the embankment on either side of the pipeline crossing.

On the Mildred Island side, the probability of failure of each pipeline was assessed by considering the proportion of the embankment length over which a breach could occur and impact the pipeline. The assessed failure probabilities, given an inward breach on Bacon Island embankment, were 6% and 2%, respectively, for the northern and southern gas pipelines. On the Palm Tract side, the assessed probability of pipeline failure was 2% (See Table 14).

The cost of repairing the pipelines, downtime of the northern pipeline during which gas service would be interrupted, and the loss of revenue during downtime were estimated based on information obtained from PG&E. The unit cost of pipeline repair was assumed to be $3,500 per lineal foot. The repair length of the northern/southern pipeline perpendicular to the project embankment was assumed to be 1,700 feet, which is the estimated length of land scour following an inward breach. The repair length of the northern pipeline parallel to the project embankment was assumed to be 600 feet, which is the width of the estimated land scour. The expected loss of direct revenue to PG&E in case of pipeline failure was estimated to be $2.8 million based on the information provided by PG&E personnel.

3.1.7 Impact to BNSF Railroad

The railroad between Bacon Island and Woodward Island is supported on a trestle bridge supported on piles. No direct information about the depth of piles was available. However, based on experience with similar trestle bridges, the depth of piles was expected to be 70 to 80 feet. There is also an earth embankment beneath the railroad tracts; however, it does not provide structural support to the railroad tracks.

An inward breach at the southern edge of the embankment on Bacon Island would draw water from the slough into the reservoir. This could erode the soils from the railroad embankment. However, the probability of a failure of the bridge, which is supported on piles, was assessed to be negligible.

The hydraulic analysis, which is included in Appendix B, estimated that, in the case of an inward breach in the Bacon Island embankment north of Woodward Island, the peak water velocity at the railroad embankment would be about 9 ft/sec. Making assumptions similar to those described in Section 2.6, the probability of failure of the railroad embankment under this scenario was estimated to be 50%.

Although the embankment does not provide structural support to the trestle bridge, it was assumed that the embankment would be repaired if it were to fail. The estimated cost to repair a 1000-foot-long breach in the embankment would be roughly $5 million.

3.1.8 Flooding of Project Islands Under “No Action” Scenario

This scenario addresses the probability and consequences of failure of the candidate project islands under the ”no action” (i.e., existing levee) condition. In this scenario, Webb Tract and Bacon Island are assumed to be operated as farming islands.

A breach of the existing levee on a project island (i.e., Webb Tract or Bacon Island) would flood the island and impact the current resources and infrastructure. The economic losses from these impacts were estimated. Section 3.3 describes the categories of resources that would be impacted and the data and assumptions used to estimate the economic losses. Table 6 in that section summarizes the estimated economic losses for the two project islands (and also for the neighboring islands). The current resources on the project islands (crops and infrastructure) would be lost if either the island is converted to a reservoir or the existing levee fails and the island is flooded. For the IDS project, the costs of these impacts would logically be a part of the total project cost and would not be related to the risk of failure of the project embankment. To provide a proper comparison between the estimated risks of the re-engineered project and existing levees, the consequences of flooding the project islands were excluded for all alternatives.

The risk of loss of life due to flooding was considered to be insignificant because of limited exposure and sufficient warning time. There is little permanent population inside the two project islands. Individuals involved in such activities as farming would spend only a limited time on the island. Additionally, there should be sufficient warning time to these individuals following a breach and an opportunity to move to higher ground.

3.2 CONSEQUENCES OF OUTWARD BREACH OF PROJECT EMBANKMENT

The economic losses/costs associated with the following consequences of an outward breach of the project embankment were evaluated. The dollar values associated with these economic losses/costs are summarized in Tables 12 and 14.

3.2.1 Emergency Response

Making assumptions similar to those in Section 3.1.1, the emergency response cost in case of an outward breach of project embankment (but no failure of neighboring island levee) was estimated to be $2.5 million.

3.2.2 Embankment Repair

Making assumptions similar to those in Section 3.1.2, the embankment repair cost was estimated to be $28 million.

3.2.3 Damage to Equipment

The expected cost of repairing damaged interceptor wells and integrated facilities was assumed to be the same as the cost estimated in Section 3.1.3.

3.2.4 Impact to Fish

An outward breach may damage the fish habitat in the slough. A response to damaged fish habitat may involve repairing the habitat or enhancing an off-site area associated with a natural functioning Delta system. The cost of the response action was assumed to be comparable to costs for an approved habitat restoration plan in the CALFED Ecosystem Restoration Program (CALFED, 2003). An equivalent restoration effort to repair a damaged spawning pool in an eastside Delta tributary was estimated to be $500,000. It was the judgment of the biologists on the project team that long-term damage to the fish habitat was unlikely, because the impacted area from an outward breach would be very small relative to the total Delta water channels and the impacted fish population would be expected to recover naturally. The probability that a habitat restoration action would be required was assessed to be relatively small (10%). Therefore, the expected cost of addressing fish impact was calculated to be $50,000 (0.1 x $500,000).

3.2.5 Loss of Water from the Reservoir

A conservative estimate of the water that could be lost from an outward breach of the project embankment would be approximately 35,000 acre-feet. . This volume was based on the difference between the reservoir water elevation +4ft. and the slough water elevation –1ft. times the area of the reservoir. This water would have to be subsequently pumped back into the reservoir. It was assumed that the reservoir would be refilled during the winter months following the repair. Water agencies that would receive water from the reservoir could face a reduction in water supply. It was assumed that the agencies would be able to access sources of emergency water supply to make up for the loss of water from the reservoir. The cost of pumping the make-up water was assumed to be $210 per acre-foot. This cost estimate was assumed to be similar to the cost of pumping make-up water by CCWD, SWP, and CVP users.

3.2.6 Impact to Water Quality and Water Supply

There is a potential for dissolved organic carbon (DOC) to be released with the reservoir water if an outward breach were to occur and DOC could reach intake pumps. Also, the peat material in the embankment breach may increase the total organic carbon (TOC) in the water. Because of a concern about potential health impacts of drinking contaminated water, Contra Costa Water District may interrupt the pumping operations from the Delta, disinfect the contaminated water and blend it with water from Los Vaqueros Reservoir. Making assumptions similar to those for an inward breach, the total volume of water that would have to be made up by CCWD following an outward breach was estimated to be 25,000 acre-feet and the cost of acquiring and pumping the make-up water was assumed to be $210 per acre-foot. Likewise, impacts to the SWP and CVP pumping intakes would be similar to the inward breach. Using available data for the SWP and CVP pumping operations and assuming four days of interruption, the volume of water that would be lost to SWP and CVP during an outward breach was estimated to be 50,000 acre-feet and the cost of pumping the make-up water was assumed to be $210 per acre-foot.

3.2.7 Impact to Marinas and Recreational Water Activities

The flood into the slough could cause damage to the facilities and infrastructure at the marinas in the impacted area. The marinas/docking facilities that could be impacted from an outward breach at the various reaches of each project embankment were identified from an aerial photo of the study area. Only those facilities that were within a distance of 2,000 feet along a water pathway from a potential breach location were considered, because facilities beyond this distance would not be expected to be damaged. The names of the impacted facilities were not available from the aerial photo, but marinas on the following islands were identified: Orwood, Holland Tract, and Lower Jones for a breach at Bacon Island; and Twitchell, Brannan/Andrus, and Bouldin for a breach at Webb Tract. The probability that an outward breach would damage each marina was estimated based on the width of the slough separating the reservoir island embankment and the marina. The estimated probabilities were 50%, 10%, and 0%, respectively for narrow (less than 1,000 feet wide), medium (1,000 feet to 2,000 feet wide), and wide (greater than 2,000 feet wide) sloughs. The sloughs for the marinas at Twitchell and Brannan/Andrus were assessed to be narrow in width, while the sloughs for the marinas at Bouldin, Orwood, Holland Tract, and Lower Jones Tract were assessed to be medium in width. If a marina were to be damaged, the repair cost and loss of revenues was estimated to be $200,000. This cost was estimated based on typical flood damage insurance claims for buildings and structures. The expected cost of damage to the marinas was calculated at each reservoir island by multiplying the probability of a marina being impacted by the cost of damage at the marina and summing the product over all impacted marinas.

3.2.8 Loss of Life

An outward breach may cause water to flow into the slough at high velocities. The velocities would depend on the width of the slough. The breach analysis in URS (2003c) showed velocity distributions for different slough widths. If the failure occurs at a time when there is major boating and fishing activity in the Delta, this could pose a significant hazard to the people in boats and fishermen in the zone of impact. Based on the results of breach analysis and engineering judgment, the zone of impact was assumed to extend half a mile centered on the breach location. The population at risk was estimated within the zone of impact and an empirical fatality rate was applied to estimate the expected number of fatalities.

A 1997 survey of recreation use in the Delta estimated that approximately 200,000 people use the Delta each year (Delta Protection Commission, 1997). There are 700 miles of waterways in the Delta; however, we estimate that most visitor use is concentrated in about half (350 miles) of the Delta waterways based upon the information in the 1997 survey. These concentrated use areas are located in the western portion of the Delta and include all of the waterways surrounding Bacon and Woodward islands.

The outward breach scenario is assumed to be applicable during the period of April through June when the reservoir would be expected to be full. Of the annual 200,000 users of the Delta waterways, the survey information suggested that about 70% of the users would be during May through September and about 76% would be daytime users. Furthermore, 65% of usage is estimated to be during the weekend (Friday through Sunday). Using these numbers and assuming 350 miles of Delta waterways, the average numbers of users per day per mile were estimated for the period of April through June for four different scenarios – weekend daytime, weekend nighttime, weekday day time, and weekday nighttime. Table 4 summarizes these usage numbers. To illustrate the calculations, consider weekend daytime scenario. The average number of users in this scenario during May through September would be 200,000 x 0.7 x 0.76 x 0.65 = 69,160. The number of days in this scenario is approximately 3/7 x 153 = 66. Then the average number of users in this scenario per day per mile of Delta waterway would 69,160/(66 x 350) = 3. The conditional probability of a breach in this scenario given that a breach does occur is 3/7 x 0.5 = 0.21.

Based on the analysis of wave velocities resulting from a breach of the reservoir island, it was conservatively assumed that people within a distance of about a half-mile from the breach location would be vulnerable to the risk of drowning. The fatality rate for people exposed to this risk was assumed to be 10%. This was based on the judgment that most boats within the zone of vulnerability would be able to withstand the impact of waves without capsizing. Also, people fishing on the shoreline would be farther away from the breach location and most would be able to survive the impact of the slower waves reaching the shore.

The expected number of fatalities given an outward breach was calculated based on the expected number of people within the vulnerability zone and the assumed fatality rate. The results are summarized in Table 4. Thus, for example, the expected number of fatalities for the weekend daytime scenario is 0.21 x 3 x 0.1 = 0.063 fatalities per breach event (which is a very low risk).

For purposes of cost-benefit analysis, government agencies have recommended the use of “value of a statistical life (VSL)”. The VSL is the amount of money one would be “willing to pay” (i.e., willing to invest in a safety improvement action) in order to reduce the expected number of fatalities by one. This concept is appropriate to use in justifying a project that is expected to provide safety benefits (i.e., to reduce the expected number of fatalities). By no means should the VSL be misconstrued as the worth of a human life. Based on guidelines provided by the U. S. Department of Transportation and U. S. Environmental Protection Agency, a VSL of $3 million was used in this analysis.

3.2.9 Impact to Mokelumne Aqueduct, Kinder Morgan Pipeline and BNSF Railroad

An outward breach along the southern edge of the embankment on Bacon Island could cause water flowing at high velocities into the slough towards the Mokelumne Aqueduct, Kinder Morgan pipeline, and BNSF railroad and create a potential for failure of one or more of these three facilities. Three different scenarios of impacting these resources from an outward breach on Bacon island were analyzed: (1) the breach occurs on the portion of the embankment in front of Woodward Island; (2) the breach occurs on the southeastern edge of the embankment in front of Upper Jones Tract; and (3) the breach occurs on the southwestern edge in front of Orwood Tract. The probability and consequences of failure under each scenario were assessed separately, as described below.

Scenario 1: Breach in Front of Woodward Island

Under this scenario, an outward breach must cause overtopping and/or washing out of the BNSF railroad embankment and cause a failure of the levee on Woodward Island before the Mokelumne Aqueduct or the Kinder Morgan pipeline could be impacted (see locations of pipelines on Figure 3). The hydraulic analysis presented in Appendix B shows that the peak water velocity at the BNSF railroad embankment would be about 14 ft/sec. However, as noted in Section 3.1.8, the embankment does not provide structural support to the railroad bridge and tracks, which are supported on a trestle bridge that rests on deep piles. Hence, the probability of failure of the railroad bridge and tracks under this scenario was assessed to be negligible. Nonetheless, it was assumed that the railroad embankment, if breached, would be repaired, and the estimated repair cost would be roughly $5 million to repair a 1000-foot-long breach in the embankment (same as for the inward breach scenario).

The hydraulic analysis estimated that the peak velocity at the levee of Woodward Island would be about 11 ft/sec. The corresponding probability of failure of the levee was estimated to be 75%. The probability that flood-fighting measures to protect Woodward Island would be unsuccessful was assessed to be 0.9. Thus, the probability that the levee on Woodward Island would fail given an outward breach at this location was calculated to be (0.9 x 0.75 =) 0.675. If the levee on Woodward Island were to fail following an outward breach on Bacon Island, this would cause a scour inside Woodward Island. As discussed previously, the average dimensions of a scour were estimated to be 1,700 feet long, 600 ft wide, and 50 ft feet deep. It was judged that the Mokelumne Aqueducts, which are supported on piles that are 30 to 40 feet deep, would most likely fail given the expected depth of scour. The probability of failure of the Mokelumne Aqueducts under this scenario was assessed to be 80%.

Cost impacts of a failure of the Mokelumne Aqueducts were estimated using information provided by EBMUD and standard cost estimation procedures. The repair cost for the three pipelines was estimated to be $36.7 million. It was assumed that the three pipelines would be repaired and brought back to service sequentially and the repair time for each pipeline would be 30 days. The volume of water to be made up following the pipeline repairs was estimated based on the rated flows in the three pipelines under gravity, which are 105, 52, and 40 MGD. The downtimes were assumed to be 30, 60, and 90 days, respectively, for these three pipelines. Thus, the total volume of water to be made up was calculated as (30 x 105 + 60 x 52 + 40 x 90) = 9,870 million gallons (30,290 acre-feet). Based on information provided in DWR (2004), the unit pumping cost for this water was estimated to be $210 per acre-foot. Thus, the total cost of pumping the make-up water is estimated to be about $6.4 million.

Information on the potential repair cost and revenue loss due to failure of the Kinder Morgan pipeline was unavailable from Kinder Morgan. However, information provided by DWR indicates that the Kinder Moran pipeline is a buried steel 10-inch diameter pipeline. The installed cost for such a pipeline is estimated at $200 per lineal foot, which was used to estimate the cost to repair the pipeline that crosses Woodward Island. Based on an assumed 600-foot-long section of pipe that may be damaged due to a scour hole caused by a breach, the repair cost is estimated to be $120,000. Information is unavailable on potential revenue loss and, therefore, this cost could not be assessed for this draft of the risk analysis. Furthermore, based on the available information, it appears that the product flowing through the pipeline could result in environmental clean-up efforts and associated costs if the pipeline were to rupture. The potential for revenue loss and environmental clean-up cost information is being sought and will be included in an updated draft.

The cost impacts of a failure of the levee on Woodward Island are estimated in Section 3.3 below.

Scenario 2: Breach on the Southeastern Edge of Embankment in front of Upper Jones Tract

Under this scenario, an outward breach could cause a failure of the Mokelumne Aqueducts, Kinder Morgan pipeline, BNSF railroad, and/or the levee on Upper Jones Tract.

The hydraulic analysis estimated that the depth of scour in the slough (Middle River) at the Mokelumne Aqueducts under this breach scenario would be about 11 feet. Aqueduct # 3 is buried about 20 feet below ground and hence would not be exposed because of the scour. The other two aqueducts are supported on piles that are 30 to 40 feet deep. It was assumed that the scour might expose the pipes, but the piles would maintain their structural integrity. Therefore, the probability of a failure of any of the aqueducts due to scour was judged to be negligible. Based on the data from the June 3, 2004 Jones Tract flooding event, the scour dimensions were estimated to be 300 ft. x 200 ft. x 50 ft. (length x width x depth) based on topographic data provided by DWR and the cost of scour backfill was estimated to be one million dollars.

It was assumed that the Kinder Morgan pipeline would be placed in a trench with gravel bedding where it crosses the slough at Middle River. The repair cost was assumed to be roughly $180,000. Similar to Scenario 1, the potential for revenue loss and environmental clean-up cost would need to be included when such information becomes available.

The depth of scour at the railroad bridge abutment at the edge of Upper Jones Tract was estimated to be about 23 feet based on topographic data provided by DWR. Because the bridge is supported on piles that are expected to be 70 to 80 feet deep, the probability that the bridge itself would fail because of the scour impact was assessed to be negligible. However, the scour was assumed to cause a failure of the railroad embankment beyond the bridge abutment and displacement of railroad tracks. This railroad failure mode is consistent with the railroad failure that occurred due to flooding of the Lower Jones Tract and the scour at the bridge abutment following the June 3, 2004 levee breach. Using the information provided by BNSF RR Company for the June 3, 2004 Jones Tract failure event, the cost of railroad repairs was estimated to be $8 million and the loss of revenue due railroad service interruption was estimated to be $15 million.

The hydraulic analysis described in Appendix B estimated the peak velocity at the levee on Upper Jones Tract to be 9 ft/sec. The corresponding probability of failure of this levee was calculated to be 50% using the procedure described in Section 2.6. The cost impacts of a failure of the levee on Upper Jones Tract are estimated in Section 3.3 below.

<u>Scenario 3:</u> Breach on the Southwestern Edge of Embankment in front of Orwood Tract

Under this scenario, an outward breach could impact the railroad bridge embankment, the Mokelumne Aqueducts, Kinder Morgan pipeline, BNSF railroad, and the levee on Orwood Tract.

The depth of scour in the slough at the Mokelumne Aqueducts under this breach scenario was estimated to be 9 feet. As noted above, the probability of failure of the Mokelumne Aqueducts due to scour in the slough was assessed to be negligible and the cost of scour backfill around the aqueducts was estimated to be one million dollars.

The hydraulic analysis described in Appendix B estimated the peak velocity at the levee on Orwood Tract to be about 8 ft/sec. The corresponding probability of failure of this levee was calculated to be 25% using the procedure described in Section 2.6. If Orwood Tract were to be flooded, the impact on the Mokelumne Aqueducts was assumed to be similar to that for Woodward Island under Scenario 1. The cost impacts of a failure of the levee on Orwood Tract are estimated in Section 3.3 below.

The repair cost of the Kinder Morgan pipeline where it crosses the slough at Old River was assumed to be the same as the repair cost for the Middle River crossing ($180,000). Like Scenario 2, the potential for revenue loss and environmental clean-up cost would need to be included when such information becomes available.

The depth of scour at the railroad bridge abutment on the west side of Old River was estimated to be about 22 feet (See Appendix B). As discussed under Scenario 2, such scour was assumed to result in a failure of the railroad embankment and displacement of railroad tracks. The cost impact of railroad embankment failure was estimated based on the data obtained from the BNSF RR Company following the June 3, 2004 Jones Track flooding. The estimated costs of railroad repairs and consequent loss of revenue were $8 million and $15 million, respectively.

3.2.10 Stockton Ship Channel and Bradford Island

The Stockton Ship Channel (within the San Joaquin River) passes around the north side of Webb Tract. The river is about ½-mile wide where it is adjacent to Webb Tract. If an outward breach were to occur in the reservoir embankment at Webb Tract, soils would be transported to the San Joaquin River. However, due to the width of the river, it is considered unlikely that a breach in the northern reservoir embankment at Webb Tract would have a significant impact on the ship channel.

An outward breach of the west embankment of Webb Tract could cause a breach of the Bradford Island levee and flooding of this island. Table 15 includes the cost of this breach scenario.

3.3 CONSEQUENCES OF FLOODING OF NEIGHBORING ISLANDS

In the event of an outward breach on the reservoir-island embankment caused by operational loading, the levee on the island adjoining the breach may also fail. Such a failure could occur due to the impact of waves generated from the reservoir island breach. The probability of failure of the levee depends on the width of the slough separating the two islands and on the success of any flood fighting measures that may be undertaken. The greater the width of the slough separating the two islands, the less severe would be the threat to the integrity of the neighboring island levee and lower would be the probability of a levee breach on the neighboring island.

The failure of the levee on a neighboring island would result in flooding of the island. As noted in Section 1.2, the consequences of flooding of a neighboring island would be included in this risk analysis only if an outward breach of the reservoir island was triggered under operational loading, and this breach triggered a failure of the levee on a neighboring island.

The economic losses from various consequences of flooding a neighboring island were estimated using the data sources shown in Table 5. The approach to estimating the various losses are described in the sections below and the dollar values are summarized in Table 6. For the sake of completeness, Table 6 also includes the various losses from flooding the project islands, although, as noted in Section 3.1.5, these losses were not included in the estimated dollar risk.

The risk of loss of life from the flooding of a neighboring island was considered to be insignificant. This is because there should be sufficient warning time to any individuals inside the neighboring island following a breach of the reservoir island and the individuals should be able to evacuate. It is worth noting that the Jones Tract failure of June 3, 2004 did not cause any loss of life.

3.3.1 Emergency Response

It was assumed that the emergency response cost per square foot of a flooded island following the flooding of a neighboring island would be similar to that experienced during the Jones Tract event of June 3, 2004. As shown in Appendix A, the emergency response cost (including the cost of pumping out water) for the Jones Tract event was estimated to be about $31 million. The area of Upper Jones and Lower Jones Tracts was estimated to be 12,093 acres. Thus, the unit emergency response cost per acre was calculated to be $2,560. For each neighboring island, this unit cost was multiplied by the area of the island to estimate the emergency response cost for that island.

3.3.2 Repair of Levee Breach

The cost of a breach repair was assumed to be $25.8 million based on the data compiled for the Jones Tract breach closure (see Section 3.1.2).

3.3.3 Repair of Buildings

The number of buildings on adjacent islands was estimated by counting the number of structures mapped on the U.S. Geological Survey 7.5 minute quadrangles. These buildings were cross-checked using a recent aerial photo of the study area. The average repair cost per building was estimated using the data on building repairs on Upper Jones and Lower Jones Tracts following the June 3, 2004 event. The estimated number of buildings (residences, business, and farm) on Upper and Lower Jones Tracts was 75 based on the USGS maps and aerial photo. The building repair costs following the Jones Tract flooding were estimated to be $27 million as summarized in Appendix A. Using these numbers, the unit cost of building repair was calculated to be

$360,000 per building. This unit cost was multiplied by the estimated number of buildings on each neighboring island to estimate the total building repair cost for the island if it were flooded.

3.3.4 Repair of Infrastructure

The length of road corridors on each of the adjacent islands was estimated based upon the overlap of GIS road centerlines acquired from the Bay Area Regional Database (BARD). This data included all primary, secondary, and unimproved roads included in the U.S. Geological Survey's 1:100,000 digital line graph GIS data (U.S. Geological Survey, 2002). The number of bridges connecting to adjacent islands was estimated by counting the number of bridged water crossings on the U.S. Geological Survey 7.5 minute quadrangles. These bridges were cross-checked using a recent aerial photo of the study area. The length of railroad corridors on each of the adjacent islands was estimated based upon intersections with railroads documented in the National Transportation Atlas Data (NTAD) acquired from the Bureau of Transportation Statistics (2002).

The unit cost of road replacement was assumed to be $1 million per mile. The replacement cost of a small bridge was estimated to be $500,000 and the bridge repair cost was assumed to be about 5% of the replacement cost. Thus, the estimated bridge repair cost was 0.05 x $500,000 = $25,000.

For the railroad, the project team used the data provided by BNSF RR regarding railroad repair cost and loss of revenue following the June 3, 2004 Jones Tract flooding. The estimated railroad repair cost was $8 million and the estimated loss of revenue was about $15 million.

3.3.5 Impact to Agricultural Resources

Economic losses were estimated from the destruction of existing crops and the loss of future farming during the period in which the land could not be used for farming.

Crop acreages were calculated using GIS data developed by the California Department of Conservation's Farmland Mapping and Monitoring Program (California Department of Conservation, 2002). Farmland maps are updated every other year. Individual crop types are not differentiated in the farmland mapping data. Our totals included all of the polygons (i.e., unit areas) with the following attributes:

- Prime Farmland
- Farmland of Statewide Importance
- Unique Farmland
- Farmland of Local Importance
- Farmland of Local Potential
- Irrigated Farmland
- Non-Irrigated Farmland
- Irrigated Pasture
- Non-Irrigated Grain

The crop area estimates did not include land identified as grazing land, urban and built-up land, other land, or water.

Total estimated losses were based upon the assumption that two crop seasons would be affected (current and subsequent).

Losses would vary depending upon the season of inundation. There is no specific data on crop types in the study area, but it is reasonable to assume that at least 70% of the crops are summer field crops that would be affected by inundation if the breach occurred between March 1 and November 1. The remaining 30% of cropland may consist of orchards, alfalfa, or other perennial crops that would be affected by inundation during the winter months.

The estimated value of the loss would be approximately $640 per acre based upon the average California field crop values shown in Table 7. However, the data on crop damage from the Jones Tract event resulted in a unit loss of about $780 per acre. The more conservative number of $780 per acre was used in this analysis.

3.3.6 Impact to Natural Habitats

Natural habitat area was estimated using the California Natural Diversity Data Base (CNDDB) GIS data (CDFG, 2002). Estimates of natural habitat for each island are derived from the intersection of all CNDDB polygons and the perimeter of each of the adjacent islands. The overlapping areas of CNDDB polygons were counted only once. An average cost of habitat restoration in the Delta was assumed to be similar to the cost of the approved habitat restoration plan in the CALFED Ecosystem Restoration Program, which is $50,000/acre (CALFED, 2002).

3.3.7 Impact to Water Quality and Water Supply

If the flooding of a neighboring island were preceded by an outward breach of the project reservoir, there would be an initial outflow of substantial fresh water from the reservoir into the Delta channels and the failed island. This outflow of fresh water from the reservoir would mitigate to some extent the adverse impact on Delta water salinity level due to subsequent flooding of a neighboring island. A reasonable assumption would be that the impact to water supply would be about one-third of that experienced during the Jones Tract failure. The water export reduction during the Jones Tract failure was about 30,000 acre-feet. Data on water quality following the Jones Tract flooding suggests that salt-water intrusion was not a significant issue. Water quality inside the Jones Tract was affected by higher concentrations of dissolved organic carbon (DOC). However, based on the data provided by DWR, none of the urban intakes of water experienced significant impact of DOC due to Jones Tract pump-off. For this risk analysis, a water supply reduction of 10,000 acre-feet was assumed under the scenario of flooding of a neighboring island. As before, the cost of making up this water was assumed to be $210 per acre-foot.

3.3.8 Impact to Infrastructure

Flooding of Upper or Lower Jones Tract was assumed to damage the railroad embankment and tracks. Based on the June 3, 2004 Jones Tract breach, the estimated costs of railroad repairs and consequent loss of revenue were $8 million and $15 million, respectively.

The probability of failure of the Mokelumne Aqueducts due to flooding of Upper or Lower Jones Tract was assumed to be negligible. However, data from the June 3, 2004 Jones Tract flooding showed that the pipeline coating was damaged. The EBMUD cost of coating (rust-proofing) the pipelines and related cleanup was estimated to be $10.6 million. The same cost impact to the Mokelumne Aqueducts was assumed for any future flooding of the Jones Tracts.

There was no reported damage to the Kinder Morgan pipeline during the June 3, 2004 Jones Tract levee failure. Therefore, the probability of damage of the Kinder Morgan pipeline due to flooding of Upper or Lower Jones Tract was assumed to be negligible.

Flooding of Woodward Island would cause a large scour hole that would likely impact the Mokelumne Aqueducts. As discussed in Section 3.2.9, Scenario 1, the probability of failure of the Aqueducts was assessed to be 80%; the repair cost was estimated to be $36.7 million; and the cost of making up lost water supply was estimated to be $6.4 million. Likewise, flooding of Woodward Island would cause a large scour hole that would likely impact the Kinder Morgan pipeline. As discussed in Section 3.2.9, Scenario 1, the repair cost was estimated to be $120,000.

It was assumed that flooding of Orwood Tract would also cause similar impacts to the Mokelumne Aqueducts and the Kinder Morgan pipeline as described above for Woodward Island.

Risk for this project is defined as the product of the probability of a loading event, times the probability of system failure when subjected to the loading event, times the consequences of system failure. Consequences of system failure are in terms of dollar cost. Mathematically, the annual risk, *r* (i.e., probability-weighted consequences) of a given project alternative for a given reservoir island is given by:

$$r = \sum_{i} \sum_{j} n_{ij} * \sum_{k} p_{ik} * b_{ijk} * \sum_{m} s_{ijkm} * c_{ikm} \tag{1}$$

where:

n_{ij} = annual mean number of events associated with i - th loading event and j - th load level

p_{ik} = annual probability of k - th operational scenario given i - th loading event

b_{ijk} = probability of embankment failure given i - th loading event, j - th load level, and k - th operational scenario

s_{ijkm} = probability of m - th breach scenario given i - th loading event, j - th load level, and k - th operational scenario

c_{ikm} = economic losses of m - th breach scenario given i - th trigger event, and k - th operational scenario

The total risk, R during a project life of L years, assuming no discounting, is given by:

$$R = L \times r \tag{2}$$

A project life of 50 years was assumed for this analysis.

5.1 ORGANIZATION OF INPUT PARAMETERS

The input parameters for the risk analysis are organized into tables as identified below. Breach probabilities were evaluated for each of the two re-engineered project alternatives (Rock Berm and Bench) and for the "no-action" alternative.

Parameter	Table Showing Parameter Estimates
Annual mean number of events, n_{ij}	Table 8
Probabilities of operational scenarios, p_{ik}	Table 9
Probability of embankment failure, b_{ijk}	Table 10 (Failure probabilities adopted from URS, 2003a,b,c)
Probabilities of breach scenarios, s_{ijkm}	Table 11
Consequences of inward breach	Table 3
Consequences of outward breach	Table 12
Consequences of failure of related infrastructure (Mokelumne Aqueduct, BNSF Railroad, and PG&E gas pipelines)	Table 14
Probability of flooding of neighboring island caused by an outward breach on reservoir island embankment	Table 13
Consequences of flooding of neighboring islands	Table 6
Expected loss of life from an outward breach	Table 4
Summary of consequences of breach scenarios, c_{ikm}	Table 15

5.2 COMPARISON OF FAILURE RISKS OF EXISTING LEVEE AND RE-ENGINEERED PROJECT

Table 16 shows a comparison of the failure probabilities and risks under the "no-action" alternative (i.e., existing levee) and the two re-engineered alternatives at Webb Tract and Bacon Island.

In calculating the expected dollar risk for the In-Delta Storage (IDS) Project alternatives, the economic losses from the flooding of the project island were not included. This is appropriate because, for the IDS Project, the loss of current resources would not be related to the risk of failure of the project embankment and hence this consequence is logically a part of the project initial cost. Since the loss of current resources on the project island is not considered for the IDS Project alternative, a consistent risk comparison requires that the loss not be considered for the "no-action" alternative (existing levee) as well. However, for a stand-alone (i.e., non-comparative) evaluation of the risk of the existing levee, this loss may be included. Table 16 shows the expected dollar risk of the existing levee failure under both scenarios; that is, including and excluding the economic losses caused by the impact to current resources on the project island.

The expected dollar loss including the loss of current resources on the project island under existing conditions is large because multiple levee failures could occur during a period of 50 years under existing conditions. It is assumed that after a levee failure that causes flooding of a project island, the levee would be repaired and the island would be redeveloped to its current land uses. To illustrate the estimation of the economic losses from flooding of a project island under existing conditions, consider Webb Tract. Table 6 shows that the economic losses from flooding of Webb Tract would be about $49 million. Under existing conditions, the annual probability of an inward breach causing flooding of Webb Tract is about 10% (5% from flooding and 5% from operating loading). Thus, over a period of 50 years, about 5 inward breaches that cause flooding of Webb Tract would be expected. The total expected economic losses from five flooding events at Webb Tract under existing conditions would be about $245 million. This loss from flooding when added to other losses results in the expected dollar risk of $300 million under existing conditions, as shown in Table 16. Similar calculations for Bacon Island result in the expected dollar risk of $343 million under existing conditions as shown in Table 16.

Referring to Table 16, the failure probability for the existing levee is higher than for the re-engineered alternatives by factors of 7 to 10. Similarly, the expected dollar risk, excluding the loss of current resources on the project island, is also higher for the existing levee than for the re-engineered alternatives by factors of 6 to 9. The reason that the risk is substantially lower for the re-engineered alternatives is that the project embankment under either alternative would be designed and constructed in accordance with current standards and hence the probability of failure would be much lower for the embankment than for the existing levee.

A comparison of the two re-engineered alternatives shows that the probability of failure and the expected dollar risk are about the same for the two alternatives at both project islands (see Table 16). The fatality risk under both alternatives is relatively low at each project island, although it is somewhat lower for the Rock Berm alternative than for the Bench alternative. For example, the expected number of fatalities over a 50-year period under the Rock Berm alternative is about 0.0025 at either project island. This result means that the likelihood of one fatality under the Rock Berm alternative over 50 years is 1 in 400. The expected number of fatalities over a 50-year period for the Rock Berm alternative (0.0025, or 1/400) is lower than for the Bench alternative (0.0064 to 0.0073, or about 1/160 to 1/140) by a factor of about 2.5 to 3, at both Webb Tract and Bacon Island. This is because the probability of embankment failure for the Rock Berm alternative is lower under seismic loading.

A comparison of the risks for the two candidate project islands shows that the failure probabilities, the expected dollar risks, and expected number of fatalities for each alternative are about the same for both islands (see Table 16).

Table 17 shows the contributions of the three loading events to the overall failure probability and risk for each project alternative at the two candidate project islands. For the two re-engineered alternatives, operational loading contributes only about 1% to the failure probability and expected dollar risk. This is because the failure probability for the re-engineered alternatives under operational loading is very small. Flooding and seismic loading events contribute about 40% and 60%, respectively, to the failure probability and expected dollar risk for the re-engineered alternatives. The probability of failure under flooding is mostly due to overtopping, while the contribution of piping/internal erosion to the probability of failure is minor. With regard to the expected number of fatalities for the re-engineered alternatives, almost all of the contribution is from seismic loading. Flooding does not contribute to the fatality risk, because only an inward breach is possible under flooding and the fatality risk under an inward breach is negligible.

For the existing levees at the candidate project islands, both flooding and operational loading have major contributions to the failure probability and expected dollar risk, while seismic loading has a smaller contribution. This is because the overall probability of failure of the existing levees is higher under flooding and operational loading than under seismic loading.

Because of the low crest elevation of the existing levees, a 100-year flood is likely to cause overtopping.

Without the project, the existing levee on a project island could fail first under a flood event, which would reduce the likelihood of a levee failure on a neighboring island. With the project embankment, the probability of a failure of the project island embankment would be substantially reduced. This, in turn, may increase the probability that a levee on a neighboring island would fail first. However, because the perimeter of a project island embankment is only a small fraction of the total perimeter of levees on all neighboring islands, the potential increase in the probability of a levee failure on a neighboring island is likely to be relatively small. Additional engineering investigations could be performed to quantify the associated probabilities.

The overall In-Delta Storage Project "risk" is calculated as the product of the probability and cost of project failure. Although the probability of a failure for the project embankments is very low (about 1% chance in any given year), the cost of a failure, should one occur, would be relatively high (anywhere from $30 million to $140 million depending on the failure scenario). The expected (probability-weighted) cost of failure over the life of the project would be about $20 million. It is important to note that the annual failure probability and the expected dollar risk during the 50-year project life is about 6 to 10 times greater under existing conditions than for the proposed project. In other words, the In-Delta Storage Project reduces the failure probability and the economic losses by factors of 6 to 10.

The estimated risk for each reservoir island may be used in a cost-benefit analysis of the IDS Project. The benefits of the IDS Project include environmental enhancement, water revenues from users, improved water quality, and recreation. An evaluation of these benefits can be found in a DWR report (DWR, 2004). These benefits may be compared to the project cost and the expected consequences of failure analyzed in this report.

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Tables

Table 1
Load Levels for Different Loading Events

Loading Event	Load Level	Interval of Return Period in Years	Representative Return Period in Years
Flooding	1	1 to 10	5
	2	10 to 150	100
	3	150 to 450	300
	4	450 to 1,000	500
	5	> 1,000	1,000
Seismic	1	1 to 10	5
	2	10 to 100	43
	3	100 to 700	475
	4	700 to 1,500	1,000
	5	> 1,500	2,500
Operational	1	1	1

Table 2
Operational Scenarios for Different Loading Events

Loading Event	Operational Scenario	Months of Operation in a Year in This Scenario	Comments
Flooding	Slough water level high (elevation +from 6.6' to 8.0), reservoir empty (elevation –15')	Flooding assumed to occur during December through March; the reservoir would be empty during this time period	Potential for an inward breach of the reservoir.
Seismic	Low tide (slough water level -1'), reservoir full (elevation +4')	April through June	Potential for an outward breach of the reservoir.
	High tide (slough water level +3.5'), reservoir empty (elevation –15')	July through March	Potential for an inward breach of the reservoir.
Operational	Low tide (slough water level -1'), reservoir full (elevation +4')	April through June	Potential for an outward breach of the reservoir.
	High tide (slough water level +3.5'), reservoir empty (elevation –15'), Low fresh water flow	July through November	Potential for an inward breach of the reservoir; because of low fresh water flow, greater impact of breach to water quality
	High tide (slough water level +3.5'), reservoir empty (elevation –15'), High fresh water flow	December through March	Potential for an inward breach of the reservoir; because of high fresh water flow, less impact of breach to water quality

Table 3
Consequences of Inward Breach

	Rock Berm Alternative	Bench Alternative	No Action
Cost of Breach Repair ($000)	28,000	28,000	25,800
Unit Cost of Repairing Interceptor Well ($000/well)	40	40	40
Expected Number of Interceptor Wells Impacted by a Breach	5	5	0
Expected Cost of Repairs to Interceptor Wells ($000)	200	200	0
Unit Cost of Repairing Integrated Facility ($000/facility)	500	500	500
Probability of Damage to Integrated Facility	2.9%	2.9%	0.0%
Expected Cost of Repairs to Integrated Facilities ($000)	14.3	14.3	0.0
Total Repair Cost ($000)	**28,214**	**28,214**	**25,800**
Cost of Fish Entrainment Recovery ($000)		**10**	
Volume of Water Loss (acre-foot)		75,000	
Unit Cost of Acquiring and Pumping to Make Up for the Water Supply during Service Interruption ($/acre-foot)		210	
Total Cost of Making Up the Water Supply during Service Interruption, ($000)[1]		**15,750**	

Notes:
(1) This cost impact is assumed only for an operational failure during July through November.

Table 4
Expected Loss of Life From Outward Breach

Possible Months for Outward Breach	Time of Week	Time of Day	Proportion of a Year in This Scenario	Average Number of People in Vulnerability Zone	Fatality Rate	Expected # of Fatalities	Value of a Statistical Life, VSL ($000)	Expected Value of Loss of Life ($000)
April through June	Friday-Sunday	Day Time	0.21	3.0	10%	0.063	3,000	**189**
		Night Time	0.21	1.0	10%	0.021	3,000	**63**
	Monday-Thursday	Day Time	0.29	1.2	10%	0.035	3,000	**104**
		Night Time	0.29	0.4	10%	0.012	3,000	**35**
		Total				**0.1304**		**391**

Table 5
Data Sources Evaluated to Estimate Potential Loss of Life and Property

Category of Impact	Units	Source(s) of Data
Life	Count	Sacramento-San Joaquin Delta Recreation Survey (Delta Protection Commission 1997)
Crops	Acres	California Department of Conservation, Farmland Mapping and Monitoring Program GIS data, cost estimates from June 3, 2004 levee failure (Appendix A)
Buildings	Count	U.S.G.S 7.5 minute quadrangles / aerial photos, cost estimates from June 3, 2004 levee failure (Appendix A)
Natural Habitats	Acres	California Natural Diversity Data Base (CDFG 2002); aerial photos
Railroads	Miles	U.S.G.S 7.5 minute quadrangles/ U.S.G.S. digital line graph 1:100,000 scale GIS data, cost estimates from June 3, 2004 levee failure (Appendix A)
Roads	Miles	U.S.G.S 7.5 minute quadrangles
Bridges	Count	U.S.G.S 7.5 minute quadrangles / aerial photos
Gas pipelines	Miles	U.S.G.S 7.5 minute quadrangles/ U.S.G.S. digital line graph 1:100,000 scale GIS data
Marinas	Count	Aerial photos; Hal Schell's Delta Map and Guide (August 1995 Edition)

Table 6
Consequences of Flooding of Islands (1 of 9)

Island	Facility / Resource Impacted	Inventory Unit	Number of Units Impacted	Unit Economic Loss ($000 per Inventory Unit)	Economic Loss ($000) from Flooding per Resource	Total Economic Loss ($000) from Flooding	Slough Width, Very Wide, Wide, Medium, or Narrow	Probability of Flooding Given Outward Breach of Embank-ment (from Table 13)	Expected Economic Losses ($000)
Webb Tract									
Webb Tract (5400.24 Acres)	Emergency Response	Count	1	2,500	2,500	48,851			**48,851**
	Crops	Acres	5,270	0.78	4,111				
	Buildings	Count	4	360	1,440				
	Natural Habitats	Acres	0	50	0				
	Perimeter (external levee)	Breach	1	25,800	25,800				
	Railways	Count	0	23,000	0				
	Roadways	Miles	15	1,000	15,000				
	Bridges	Count	0	25	0				
	Gas/Liquid Pipelines	Miles	0	1,143	0				
	Fish Entrainment Recovery	Breach	0	10	0				
	Aqueducts	-	-	-	0				
	Water Supply Impact	Acre-feet	0	0.07	0				
Bethel Island / Franks Tract (3514.6 Acres)	Emergency Response	Acres	3,515	2.56	8,997	236,080	Very Wide	0%	**0**
	Crops	Acres	5,510	0.78	4,298				
	Buildings	Count	500	360	180,000				
	Natural Habitats	Acres	5	50	250				
	Perimeter (external levee)	Breach	1	25,800	25,800				
	Railways	Count	0	23,000	0				
	Roadways	Miles	16	1,000	16,000				
	Bridges	Count	1	25	25				
	Gas/Liquid Pipelines	Miles	0	1,143	0				
	Fish Entrainment Recovery	Breach	1	10	10				
	Aqueducts	-	-	-	0				
	Water Supply Impact	Acre-feet	10,000	0.07	700				

Table 6
Consequences of Flooding of Islands (2 of 9)

Webb Tract

Island	Facility / Resource Impacted	Inventory Unit	Number of Units Impacted	Unit Economic Loss ($000 per Inventory Unit)	Economic Loss ($000) from Flooding per Resource	Total Economic Loss ($000) from Flooding	Slough Width, Very Wide, Wide, Medium, or Narrow	Probability of Flooding Given Outward Breach of Embank-ment (from Table 13)	Expected Economic Losses ($000)
Bradford Island (2170.4 Acres)	Emergency Response	Acres	2,170	2.56	5,556	47,952	Narrow	45%	**21,578**
	Crops	Acres	4,212	0.78	3,286				
	Buildings	Count	35	360	12,600				
	Natural Habitats	Acres	0	50	0				
	Perimeter (external levee)	Breach	1	25,800	25,800				
	Railways	Count	0	23,000	0				
	Roadways	Miles	0	1,000	0				
	Bridges	Count	0	25	0				
	Gas/Liquid Pipelines	Miles	0	1,143	0				
	Fish Entrainment Recovery	Breach	1	10	10				
	Aqueducts	-	-	-	0				
	Water Supply Impact	Acre-feet	10,000	0.07	700				
Twitchel Island (3627.2 Acres)	Emergency Response	Acres	3,627	2.56	9,286	76,319	Wide	3%	**1,908**
	Crops	Acres	7,184	0.78	5,604				
	Buildings	Count	25	360	9,000				
	Natural Habitats	Acres	281	50	14,070				
	Perimeter (external levee)	Breach	1	25,800	25,800				
	Railways	Count	0	23,000	0				
	Roadways	Miles	12	1,000	11,800				
	Bridges	Count	2	25	50				
	Gas/Liquid Pipelines	Miles	0	1,143	0				
	Fish Entrainment Recovery	Breach	1	10	10				
	Aqueducts	-	-	-	0				
	Water Supply Impact	Acre-feet	10,000	0.07	700				

Table 6
Consequences of Flooding of Islands (3 of 9)

Webb Tract

Island	Facility / Resource Impacted	Inventory Unit	Number of Units Impacted	Unit Economic Loss ($000 per Inventory Unit)	Economic Loss ($000) from Flooding per Resource	Total Economic Loss ($000) from Flooding	Slough Width, Very Wide, Wide, Medium, or Narrow	Probability of Flooding Given Outward Breach of Embank-ment (from Table 13)	Expected Economic Losses ($000)
Brannan Island / Andrus Island (15263.4 Acres)	Emergency Response	Acres	15,263	2.56	39,074	593,559	Wide	3%	**14,839**
	Crops	Acres	28,398	0.78	22,150				
	Buildings	Count	500	360	180,000				
	Natural Habitats	Acres	5,170	50	258,475				
	Perimeter (external levee)	Breach	1	25,800	25,800				
	Railways (2.7 miles of abandoned RR)	Count	0	23,000	0				
	Roadways	Miles	67	1,000	67,100				
	Bridges	Count	10	25	250				
	Gas/Liquid Pipelines	Miles	0	1,143	0				
	Fish Entrainment Recovery	Breach	1	10	10				
	Aqueducts	-	-	-	0				
	Water Supply Impact	Acre-feet	10,000	0.07	700				
Bouldin Island (5994.3 Acres)	Emergency Response	Acres	5,994	2.56	15,345	390,627	Wide	3%	**9,766**
	Crops	Acres	11,694	0.78	9,121				
	Buildings	Count	20	360	7,200				
	Natural Habitats	Acres	6,028	50	301,400				
	Perimeter (external levee)	Breach	1	25,800	25,800				
	Railways	Count	0	23,000	0				
	Roadways	Miles	31	1,000	31,000				
	Bridges	Count	2	25	50				
	Gas/Liquid Pipelines	Miles	0	1,143	0				
	Fish Entrainment Recovery	Breach	1	10	10				
	Aqueducts	-	-	-	0				
	Water Supply Impact	Acre-feet	10,000	0.07	700				

Table 6
Consequences of Flooding of Islands (4 of 9)

Island	Facility / Resource Impacted	Inventory Unit	Number of Units Impacted	Unit Economic Loss ($000 per Inventory Unit)	Economic Loss ($000) from Flooding per Resource	Total Economic Loss ($000) from Flooding	Slough Width, Very Wide, Wide, Medium, or Narrow	Probability of Flooding Given Outward Breach of Embank-ment (from Table 13)	Expected Economic Losses ($000)
Webb Tract									
Venice Island (3120.6 Acres)	Emergency Response	Acres	3,121	2.56	7,989	212,419	Wide	3%	**5,310**
	Crops	Acres	5,750	0.78	4,485				
	Buildings	Count	5	360	1,800				
	Natural Habitats	Acres	3,159	50	157,935				
	Perimeter (external levee)	Breach	1	25,800	25,800				
	Railways	Count	0	23,000	0				
	Roadways	Miles	14	1,000	13,700				
	Bridges	Count	0	25	0				
	Gas/Liquid Pipelines	Miles	0	1,143	0				
	Fish Entrainment Recovery	Breach	1	10	10				
	Aqueducts	-	-	-	0				
	Water Supply Impact	Acre-feet	10,000	0.07	700				
Mandeville Island (5215.3 Acres)	Emergency Response	Acres	5,215	2.56	13,351	213,066	Wide	3%	**5,327**
	Crops	Acres	9,846	0.78	7,680				
	Buildings	Count	10	360	3,600				
	Natural Habitats	Acres	2,722	50	136,100				
	Perimeter (external levee)	Breach	1	25,800	25,800				
	Railways	Count	0	23,000	0				
	Roadways	Miles	26	1,000	25,800				
	Bridges	Count	1	25	25				
	Gas/Liquid Pipelines	Miles	0	1,143	0				
	Fish Entrainment Recovery	Breach	1	10	10				
	Aqueducts	-	-	-	0				
	Water Supply Impact	Acre-feet	10,000	0.07	700				

Table 6
Consequences of Flooding of Islands (5 of 9)

Bacon Island

Island	Facility / Resource Impacted	Inventory Unit	Number of Units Impacted	Unit Economic Loss ($000 per Inventory Unit)	Economic Loss ($000) from Flooding per Resource	Total Economic Loss ($000) from Flooding	Slough Width, Very Wide, Wide, Medium, or Narrow	Probability of Flooding Given Outward Breach of Embank-ment (from Table 13)	Expected Economic Losses ($000)
Bacon Island (5452.06 Acres)	Emergency Response	Count	1	2,500	2,500	80,395			**80,395**
	Crops	Acres	5,250	0.78	4,095				
	Buildings	Count	75	360	27,000				
	Natural Habitats	Acres	0	50	0				
	Perimeter (external levee)	Breach	1	25,800	25,800				
	Railways	Count	0	23,000	0				
	Roadways	Miles	21	1,000	21,000				
	Bridges	Count	0	25	0				
	Gas/Liquid Pipelines	Miles	0	1,143	0				
	Fish Entrainment Recovery	Breach	0	10	0				
	Aqueducts	-	-	-	0				
	Water Supply Impact	Acre-feet	0	0.07	0				
Woodward Island (1833.3 Acres)	Emergency Response	Acres	1,833	2.56	4,693	83,537	Narrow (Probability based on estimated peak velocity, see Appendix B)	67.5%	**56,388**
	Crops	Acres	3,378	0.78	2,635				
	Buildings	Count	15	360	5,400				
	Natural Habitats	Acres	42	50	2,100				
	Perimeter (external levee)	Breach	1	25,800	25,800				
	Railways	Count	0	23,000	0				
	Roadways	Miles	9	1,000	9,000				
	Bridges	Count	0	25	0				
	Gas/Liquid Pipelines (from Table 14)	-	-	-	120				
	Fish Entrainment Recovery	Breach	1	10	10				
	Aqueducts (from Table 14)	-	-	-	33,079				
	Water Supply Impact	Acre-feet	10,000	0.07	700				

Table 6
Consequences of Flooding of Islands (6 of 9)

Bacon Island									
Island	**Facility / Resource Impacted**	**Inventory Unit**	**Number of Units Impacted**	**Unit Economic Loss ($000 per Inventory Unit)**	**Economic Loss ($000) from Flooding per Resource**	**Total Economic Loss ($000) from Flooding**	**Slough Width, Very Wide, Wide, Medium, or Narrow**	**Probability of Flooding Given Outward Breach of Embank-ment (from Table 13)**	**Expected Economic Losses ($000)**
Orwood Tract (2310.0 Acres)	Emergency Response	Acres	2,310	2.56	5,914	95,104	Medium	18%	**16,643**
	Crops	Acres	4,405	0.78	3,436				
	Buildings	Count	35	360	12,600				
	Natural Habitats	Acres	15	50	745				
	Perimeter (external levee)	Breach	1	25,800	25,800				
	Railways	Count	0	23,000	0				
	Roadways	Miles	12.7	1,000	12,700				
	Bridges	Count	0	25	0				
	Gas/Liquid Pipelines (from Table 14)	-	-	-	120				
	Fish Entrainment Recovery	Breach	1	10	10				
	Aqueducts (from Table 14)	-	-	-	33,079				
	Water Supply Impact	Acre-feet	10,000	0.07	700				
Palm Tract (2524.5 Acres)	Emergency Response	Acres	2,525	2.56	6,463	68,180	Narrow	45%	**30,681**
	Crops	Acres	4,798	0.78	3,742				
	Buildings	Count	15	360	5,400				
	Natural Habitats	Acres	2	50	115				
	Perimeter (external levee)	Breach	1	25,800	25,800				
	Railways	Count	0	23,000	0				
	Roadways	Miles	17	1,000	17,200				
	Bridges	Count	0	25	0				
	Gas/Liquid Pipelines (from Table 14)	-	-	-	8,750				
	Fish Entrainment Recovery	Breach	1	10	10				
	Aqueducts	-	-	-	0				
	Water Supply Impact	Acre-feet	10,000	0.07	700				

Table 6
Consequences of Flooding of Islands (7 of 9)

Bacon Island									
Island	**Facility / Resource Impacted**	**Inventory Unit**	**Number of Units Impacted**	**Unit Economic Loss ($000 per Inventory Unit)**	**Economic Loss ($000) from Flooding per Resource**	**Total Economic Loss ($000) from Flooding**	**Slough Width, Very Wide, Wide, Medium, or Narrow**	**Probability of Flooding Given Outward Breach of Embank-ment (from Table 13)**	**Expected Economic Losses ($000)**
Holland Tract (4225.4 Acres)	Emergency Response	Acres	4,225	2.56	10,817	77,449	Narrow	45%	**34,852**
	Crops	Acres	8,304	0.78	6,477				
	Buildings	Count	25	360	9,000				
	Natural Habitats	Acres	4	50	195				
	Perimeter (external levee)	Breach	1	25,800	25,800				
	Railways	Count	0	23,000	0				
	Roadways	Miles	24	1,000	24,400				
	Bridges	Count	2	25	50				
	Gas/Liquid Pipelines	Miles	0	1,143	0				
	Fish Entrainment Recovery	Breach	1	10	10				
	Aqueducts	-	-	-	0				
	Water Supply Impact	Acre-feet	10,000	0.07	700				
Quimby Island (812.3 Acres)	Emergency Response	Acres	812	2.56	2,079	35,025	Very Wide	0%	**0**
	Crops	Acres	1,481	0.78	1,155				
	Buildings	Count	0	360	0				
	Natural Habitats	Acres	106	50	5,280				
	Perimeter (external levee)	Breach	1	25,800	25,800				
	Railways	Count	0	23,000	0				
	Roadways	Miles	0	1,000	0				
	Bridges	Count	0	25	0				
	Gas/Liquid Pipelines	Miles	0	1,143	0				
	Fish Entrainment Recovery	Breach	1	10	10				
	Aqueducts	-	-	-	0				
	Water Supply Impact	Acre-feet	10,000	0.07	700				

Table 6
Consequences of Flooding of Islands (8 of 9)

Bacon Island

Island	Facility / Resource Impacted	Inventory Unit	Number of Units Impacted	Unit Economic Loss ($000 per Inventory Unit)	Economic Loss ($000) from Flooding per Resource	Total Economic Loss ($000) from Flooding	Slough Width, Very Wide, Wide, Medium, or Narrow	Probability of Flooding Given Outward Breach of Embank-ment (from Table 13)	Expected Economic Losses ($000)
Mandeville Island (5215.3 Acres)	Emergency Response	Acres	5,215	2.56	13,351	213,066	Narrow	45%	**95,880**
	Crops	Acres	9,846	0.78	7,680				
	Buildings	Count	10	360	3,600				
	Natural Habitats	Acres	2,722	50	136,100				
	Perimeter (external levee)	Breach	1	25,800	25,800				
	Railways	Count	0	23,000	0				
	Roadways	Miles	26	1,000	25,800				
	Bridges	Count	1	25	25				
	Gas/Liquid Pipelines	Miles	0	1,143	0				
	Fish Entrainment Recovery	Breach	1	10	10				
	Aqueducts	-	-	-	0				
	Water Supply Impact	Acre-feet	10,000	0.07	700				
Mildred Island / McDonald Tract (6068.5 Acres)	Emergency Response	Acres	6,069	2.56	15,535	102,514	Very Wide	0%	**0**
	Crops	Acres	11,479	0.78	8,953				
	Buildings	Count	50	360	18,000				
	Natural Habitats	Acres	10	50	490				
	Perimeter (external levee)	Breach	1	25,800	25,800				
	Railways	Count	0	23,000	0				
	Roadways	Miles	33	1,000	33,000				
	Bridges	Count	1	25	25				
	Gas/Liquid Pipelines	Miles	0	1,143	0				
	Fish Entrainment Recovery	Breach	1	10	10				
	Aqueducts	-	-	-	0				
	Water Supply Impact	Acre-feet	10,000	0.07	700				

Table 6
Consequences of Flooding of Islands (9 of 9)

Bacon Island

Island	Facility / Resource Impacted	Inventory Unit	Number of Units Impacted	Unit Economic Loss ($000 per Inventory Unit)	Economic Loss ($000) from Flooding per Resource	Total Economic Loss ($000) from Flooding	Slough Width, Very Wide, Wide, Medium, or Narrow	Probability of Flooding Given Outward Breach of Embank-ment (from Table 13)	Expected Economic Losses ($000)
Lower Jones Tract (5995.3 Acres)	Emergency Response	Acres	5,995	2.56	15,348	93,181	Medium	18%	**16,307**
	Crops	Acres	11,171	0.78	8,713				
	Buildings	Count	35	360	12,600				
	Natural Habitats	Acres	140	50	7,010				
	Perimeter (external levee)	Breach	1	25,800	25,800				
	Railways	Count	1	23,000	23,000				
	Roadways	Miles	0	1,000	0				
	Bridges	Count	0	25	0				
	Gas/Liquid Pipelines	Miles	0	1,143	0				
	Fish Entrainment Recovery	Breach	1	10	10				
	Aqueducts	-	-	-	0				
	Water Supply Impact	Acre-feet	10,000	0.07	700				
Upper Jones Tract (6097.4 Acres)	Emergency Response	Acres	6,097	2.56	15,609	87,095	Medium (Probability based on estimated peak velocity, see Appendix B)	35%	**30,483**
	Crops	Acres	12,003	0.78	9,363				
	Buildings	Count	40	360	14,400				
	Natural Habitats	Acres	212	50	10,620				
	Perimeter (external levee)	Breach	1	25,800	25,800				
	Railways	Count	0	23,000	0				
	Roadways	Miles	0	1,000	0				
	Bridges	Count	1	25	25				
	Gas/Liquid Pipelines	Miles	0	1,143	0				
	Fish Entrainment Recovery	Breach	1	10	10				
	Aqueducts (from Appendix A)	-	-	-	10,568				
	Water Supply Impact	Acre-feet	10,000	0.07	700				

Notes:
(1) Crops: Based upon average field crop value for 2001 of $640 per acre, and 2-crop season.
(2) Buildings: Assumes $100/sq. feet and average size of 2,000 square feet.
(3) Natural Habitats: Based upon an average cost of habitat restoration in the Delta of $50,000.
(4) Gas Pipelines: Based upon $80 million to construct 70 miles of 20-inch pipeline.

Table 7
Value of Selected Field Crops in California in 2001

Crop Type	Yield (tons per acre)	Average Price ($ per ton)	Value per Acre ($)
Corn For Grain	4.8	$89.30	$425.00
Winter Wheat For Grain	2.1	$100.00	$210.00
Hay, Alfalfa	7	$120.00	$840.00
Sugar Beets	35.7	$30.40	$1,085.30
Average	12.4	$84.90	$640.10

Source: California Agricultural Statistics Service 2002.

Table 8
Annual Mean Number of Events in Each Load Level

Loading Event, *i*	Load Level, *j*	Interval of Return Period, Years	Annual Mean Number of Events, n_{ij}
Flooding	1	1 to 10	0.9000
	2	10 to 150	0.0933
	3	150 to 450	0.0044
	4	450 to 1000	0.0012
	5	> 1000	0.0010
Seismic	1	1 to 10	0.9000
	2	10 to 100	0.0900
	3	100 to 700	0.0086
	4	700 to 1,500	0.0008
	5	> 1,500	0.0007
Operational	1	1	1.0000

Table 9
Annual Probabilities of Operational Scenarios

Loading Event, *i*	Operational Scenario, *k*	Annual Probability of Operational Scenario, p_{ik} Re-Engineered Project	Annual Probability of Operational Scenario, p_{ik} No Action (Existing Levee)
Flooding	1. Slough water level high (elevation +6.6' to 8.0'), reservoir empty (elevation –15’)	1	1
Seismic	1. Low tide (slough water level -1’), reservoir full (elevation +4’)	0.25	0
	2. High tide (slough water level +3.5’), reservoir empty (elevation –15’)	0.75	1
Operational	1. Low tide (slough water level -1’), reservoir full (elevation +4’)	0.25	0
	2. High tide (slough water level +3.5’), reservoir empty (elevation –15’), Low fresh water flow	0.42	0.56
	3. High tide (slough water level +3.5’), reservoir empty (elevation –15’), High fresh water flow	0.33	0.44

Table 10
Probability of Embankment Failure

			Webb Tract			Bacon Island		
			Rock Berm Alternative	Bench Alternative	No Action	Rock Berm Alternative	Bench Alternative	No Action
Loading Event, *i*	**Load Level, *j***	**Operational Scenario, *k***	**% Probability of Embankment Failure under Engineered Project, b_{ijk}**	**% Probability of Embankment Failure under Engineered Project, b_{ijk}**	**% Probability of Embankment Failure under "No Action" Alternative, b'_{ijk}**	**% Probability of Embankment Failure under Engineered Project, b_{ijk}**	**% Probability of Embankment Failure under Engineered Project, b_{ijk}**	**% Probability of Embankment Failure under "No Action" Alternative, b'_{ijk}**
Flooding	1. Return period = 1 to 10 years	1. Slough water level high (elevation +6.6'), reservoir empty (elevation –15')	0%	0%	0%	0%	0%	0%
	2. Return period = 10 to 150 years	1. Slough water level high (elevation +7'), reservoir empty (elevation –15')	0.0013%	0.0013%	50.4%	0.0013%	0.0013%	50.17%
	3. Return period = 150 to 450 years	1. Slough water level high (elevation +7.2'), reservoir empty (elevation –15')	50.003%	50.003%	100%	50.003%	50.003%	100%
	4. Return period = 450 to 1,000 years	1. Slough water level high (elevation +7.6'), reservoir empty (elevation –15')	100%	100%	100%	100%	100%	100%
	5. Return period greater than 1,000 years	1. Slough water level high (elevation +8'), reservoir empty (elevation –15')	100%	100%	100%	100%	100%	100%
Seismic	1. Return period = 1 to 10 years	1. Low tide (slough water level -1'), reservoir full (elevation +4')	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		2. High tide (slough water level +3.5'), reservoir empty (elevation –15')	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	2. Return period = 10 to 100 years	1. Low tide (slough water level -1'), reservoir full (elevation +4')	0.01%	0.17%	0.00%	0.01%	0.21%	0.00%
		2. High tide (slough water level +3.5'), reservoir empty (elevation –15')	0.13%	0.25%	0.48%	0.11%	0.26%	0.47%
	3. Return period = 100 to 700 years	1. Low tide (slough water level -1'), reservoir full (elevation +4')	1.71%	21.63%	0.00%	1.95%	25.87%	0.00%
		2. High tide (slough water level +3.5'), reservoir empty (elevation –15')	74.86%	74.87%	76%	78.00%	78.01%	79.21%
	4. Return period = 700 to 1,500 years	1. Low tide (slough water level -1'), reservoir full (elevation +4')	40.00%	51.00%	0%	32.50%	58.00%	0.00%
		2. High tide (slough water level +3.5'), reservoir empty (elevation –15')	86.50%	87.00%	88.0%	88.00%	88.50%	90.00%
	5. Return period greater than 1,500 years	1. Low tide (slough water level -1'), reservoir full (elevation +4')	95.00%	95.00%	0.0%	95.00%	95.00%	0.00%
		2. High tide (slough water level +3.5'), reservoir empty (elevation –15')	95.00%	95.00%	95.0%	95.00%	95.00%	95.00%
Operational	Return period = 1 year	1. Low tide (slough water level -1'), reservoir full (elevation +4')	0.0029%	0.0029%	5.0%	0.0029%	0.0029%	2.0%
		2. High tide (slough water level +3.5'), reservoir empty (elevation –15'), Low fresh water flow	0.01440%	0.01440%	5.0%	0.01440%	0.01440%	2.0%
		3. High tide (slough water level +3.5'), reservoir empty (elevation –15'), High fresh water flow	0.01440%	0.01440%	5.0%	0.01440%	0.01440%	2.0%

Table 11
Probabilities of Breach Scenarios (1 of 2)

					Webb Tract	Bacon Island	No Action
Loading Event, *i*	**Load Level, *j***	**Operational Scenario, *k***	**Breach Scenario, *m***	**Relative Length**	**Probability of Breach Scenario, s_{ijkm}**	**Probability of Breach Scenario, s_{ijkm}**	**Probability of Breach Scenario, s_{ijkm}**
Flooding	1. Return period = 1 to 10 years	1. Slough water level high (elevation +6.6'), reservoir empty (elevation –15')	One inward breach		100%	100%	100%
			Two inward breaches		0%	0%	0%
	2. Return period = 10 to 150 years	1. Slough water level high (elevation +7'), reservoir empty (elevation –15')	One inward breach		100%	100%	100%
			Two inward breaches		0%	0%	0%
	3. Return period = 150 to 450 years	1. Slough water level high (elevation +7.2'), reservoir empty (elevation –15')	One inward breach		100%	100%	100%
			Two inward breaches		0%	0%	0%
	4. Return period = 450 to 1,000 years	1. Slough water level high (elevation +7.6'), reservoir empty (elevation –15')	One inward breach		75%	75%	75%
			Two inward breaches		25%	25%	25%
	5. Return period greater than 1,000	1. Slough water level high (elevation +8'), reservoir empty (elevation –15')	One inward breach		50%	50%	50%
			Two inward breaches		50%	50%	50%
Seismic	1. Return period = 1 to 10 years	1. Low tide (slough water level -1'), reservoir full (elevation +4')	One outward breach		95.2%	95.2%	95.2%
			Two outward beaches		4.8%	4.8%	4.8%
		2. High tide (slough water level +3.5'), reservoir empty (elevation –15')	One inward breach		95.2%	95.2%	95.2%
			Two inward breaches		4.8%	4.8%	4.8%
	2. Return period = 10 to 100 years	1. Low tide (slough water level -1'), reservoir full (elevation +4')	One outward breach		90.9%	90.9%	90.9%
			Two outward beaches		9.1%	9.1%	9.1%
		2. High tide (slough water level +3.5'), reservoir empty (elevation –15')	One inward breach		90.9%	90.9%	90.9%
			Two inward breaches		9.1%	9.1%	9.1%
	3. Return period = 100 to 700 years	1. Low tide (slough water level -1'), reservoir full (elevation +4')	One outward breach		76.9%	76.9%	76.9%
			Two outward beaches		23.1%	23.1%	23.1%
		2. High tide (slough water level +3.5'), reservoir empty (elevation –15')	One inward breach		76.9%	76.9%	76.9%
			Two inward breaches		23.1%	23.1%	23.1%
	4. Return period = 700 to 1,500years	1. Low tide (slough water level -1'), reservoir full (elevation +4')	One outward breach		62.5%	62.5%	62.5%
			Two outward beaches		37.5%	37.5%	37.5%
		2. High tide (slough water level +3.5'), reservoir empty (elevation –15')	One inward breach		62.5%	62.5%	62.5%
			Two inward breaches		37.5%	37.5%	37.5%
	5. Return period greater than 1,500 years	1. Low tide (slough water level -1'), reservoir full (elevation +4')	One outward breach		52.6%	52.6%	52.6%
			Two outward beaches		47.4%	47.4%	47.4%
		2. High tide (slough water level +3.5'), reservoir empty (elevation –15')	One inward breach		52.6%	52.6%	52.6%
			Two inward breaches		47.4%	47.4%	47.4%

Table 11
Probabilities of Breach Scenarios (2 of 2)

					Webb Tract	Bacon Island	No Action
Loading Event, *i*	**Load Level, *j***	**Operational Scenario, *k***	**Breach Scenario, *m***	**Relative Length**	**Probability of Breach Scenario, s_{ijkm}**	**Probability of Breach Scenario, s_{ijkm}**	**Probability of Breach Scenario, s_{ijkm}**
Operational - Webb Tract	Return period = 1 year	1. Low tide (slough water level -1'), reservoir full (elevation +4')	Outward breach on reach in front of Bethel Island / Franks Tract	12	30%		30%
			Outward breach on reach in front of Bradford Island	8	20%		20%
			Outward breach on reach in front of Twitchell Island	6	15%		15%
			Outward breach on reach in front of Brannan Island / Andrus Island	6	15%		15%
			Outward breach on reach in front of Bouldin Island	2	5%		5%
			Outward breach on reach in front of Venice Island	2	5%		5%
			Outward breach on reach in front of Mandeville Island	4	10%		10%
		2. High tide (slough water level +3.5'), reservoir empty (elevation –15'), Low fresh water flow	One inward breach		100%		100%
		3. High tide (slough water level +3.5'), reservoir empty (elevation –15'), High fresh water flow	One inward breach		100%		100%
Operational - Bacon Island	Return period = 1 year	1. Low tide (slough water level -1'), reservoir full (elevation +4')	Outward breach on reach in front of Woodward Island	5		9%	9%
			Outward breach on reach in front of Orwood Tract	1.3		2%	2%
			Outward breach on reach in front of Palm Tract	10		18%	18%
			Outward breach on reach in front of Holland Tract	8		14%	14%
			Outward breach on reach in front of Quimby Island	5		9%	9%
			Outward breach on reach in front of Mandeville Island	8		14%	14%
			Outward breach on reach in front of Mildred Island / McDonald Tract	9		16%	16%
			Outward breach on reach in front of Lower Jones Tract	9		16%	16%
			Outward breach on reach in front of Upper Jones Tract	0.56		1%	1%
		2. High tide (slough water level +3.5'), reservoir empty (elevation –15'), Low fresh water flow	One inward breach			100%	100%
		3. High tide (slough water level +3.5'), reservoir empty (elevation –15'), High fresh water flow	One inward breach			100%	100%

Table 12
Consequences of Outward Breach

	Rock Berm Alternative	Bench Alternative	No Action
Cost of Breach Repair ($000)	28,000	28,000	25,800
Unit Cost of Repairing Interceptor Well ($000/well)	40	40	40
Expected Number of Interceptor Wells Impacted by a Breach	5	5	0
Expected Cost of Repairs to Interceptor Wells ($000)	200	200	0
Unit Cost of Repairing Integrated Facility ($000/facility)	500	500	500
Probability of Damage to Integrated Facility	2.9%	2.9%	0.0%
Expected Cost of Repairs to Integrated Facilities ($000)	14.3	14.3	0.0
Total Repair Cost ($000)	**28,214**	**28,214**	**25,800**
Cost of Mitigation to Fish Impact ($000)	500		
Probability of Requiring Mitigation	10%		
Expected Cost of Mitigation to Fish Impact ($000)	**50**		
Cost of Repairs to Facilities and Boats at Marinas for Webb Tract ($000)	**220**		
Cost of Repairs to Facilities and Boats at Marinas for Bacon Island ($000)	**60**		
Volume of Water Loss (acre-foot) due to pumping service interruption	25,000		
Volume of Water Loss from Reservoir (acre-foot)	35,000		
Unit Cost of Acquiring and Pumping to Make Up for the Water Loss ($/acre-foot)	210		
Total Cost of Making Up the Water Supply during Service Interruption, ($000)[2]	**12,600**		

Notes:
(1) Consequences of flooding of neighboring islands caused by an outward breach are shown separately in Table 6.
(2) This cost impact is assumed only for an operational failure during July through November.

Table 13
Probability of Flooding of Neighboring Island Given Outward Breach of Reservoir Island Embankment

Slough Width	Probability Wave Impact Initiates a Breach on Neighboring Island Levee, *a*	Probability that Flood Fighting Measures on Neighboring Island are Successful, *b*	Probability that Neighboring Island is Flooded due to Outward Breach of Reservoir Island, *a*(1-b)*
Very wide	0%	100%	**0.0%**
Wide	5%	50%	**2.5%**
Medium	25%	30%	**17.5%**
Narrow	50%	10%	**45.0%**

Table 14
Consequences of Failure of Related Infrastructure (Mokelumne Aqueduct, BNSF Railroad, PG&E Gas Pipelines, and Kinder Morgan Pipeline)

Loading Event, *i*	Operational Scenario, *k*	Breach Scenario, *m*	Impact	Prob.	Consequence	Dollar Cost/Loss ($000)	Expected Dollar Cost/Loss ($000)	RR Impact in Slough ($000)	Aqueduct Impact in Slough ($000)	Gas / Liquid Pipeline Impact in Slough ($000)
Operational	1. Low tide (slough water level -1'), reservoir full (elevation +4')	Outward breach on the reach in front of **Orwood Tract** (southwest corner of Bacon Island)	RR bridge support fails	0%	Bridge repair	8,000	0	23,000	1,000	180
				0%	Loss of revenue	15,000	0			
			RR bridge embankment fails	100%	RR repair	8,000	8,000			
				100%	Loss of revenue	15,000	15,000			
			Aqueduct fails	0%	Aqueduct repair	36,700	0			
				0%	Cost of making up loss of water	4,649	0			
			Scour around the aqueduct	100%	Scour backfill around the Aqueduct	1,000	1,000			
			Kinder-Morgan pipeline fails	100%	Pipeline repair	180	180			
				100%	Loss of revenue	0	0			
			Aqueduct fails due to scour given flooding of Orwood Tract	80%	Repair	36,700	29,360			
				80%	Cost of making up loss of water	4,649	3,719			
			Kinder-Morgan pipeline fails due to scour given flooding of Orwood Tract	100%	Pipeline repair	120	120			
				100%	Loss of revenue	0	0			
		Outward breach on the reach in front of **Upper Jones Tract** (southeast corner of Bacon Island)	RR bridge support fails	0%	RR repair	8,000	0	23,000	1,000	180
				0%	Loss of revenue	15,000	0			
			RR bridge embankment fails due to scour at the bridge abutment	100%	RR repairs	8,000	8,000			
				100%	Loss of revenue	15,000	15,000			
			Aqueduct fails	0%	Aqueduct repair	36,700	0			
				0%	Cost of making up loss of water	4,649	0			
			Scour around the aqueduct	100%	Scour backfill around the Aqueduct	1,000	1,000			
			Kinder-Morgan pipeline fails	100%	Pipeline repair	180	180			
				100%	Loss of revenue	0	0			
		Outward breach in front of **Woodward Island**	RR bridge embankment fails	100%	Repair	5,000	5,000	5,000		
				0%	Loss of revenue	15,000	0			
			Aqueduct fails due to scour given flooding of Woodward Island	80%	Repair	36,700	29,360			
				80%	Cost of making up loss of water	4,649	3,719			
			Kinder-Morgan pipeline fails due to scour given flooding of Woodward Island	100%	Pipeline repair	120	120			
				100%	Loss of revenue	0	0			
		Outward breach on reach in front of **Palm Tract**	Gas pipeline impacted in the slough	37.5%	Repair	2,100	787			1,836
				37.5%	Loss of revenue	2,800	1,049			
			Gas pipeline fail inside Palm Tract given flooding of Palm Tract	100%	Repair	5,950	5,950			
				100%	Loss of revenue	2,800	2,800			
		Outward breach on reach in front of **Mildred Island / McDonald Tract**	Northern gas pipeline impacted in the slough	43.8%	Repair	1,750	766			2,759
				43.8%	Loss of revenue	2,800	1,226			
			Southern gas pipeline impacted in the slough	43.8%	Repair	1,750	766			
				43.8%	Loss of revenue	0	0			
	2. High tide (slough water level +3.5'), reservoir empty (elevation –15'), Low fresh water flow <u>**or**</u> 3. High tide (slough water level +3.5'), reservoir empty (elevation –15'), High fresh water flow	Inward breach	Gas pipeline at Palm Tract impacted due to land scour	1.6%	Repair	5,950	94			505
				1.6%	Loss of revenue	2,800	44			
			Northern gas pipeline parallel to project embankment at Mildred Island impacted due to land scour	5.6%	Repair	2,100	117			
				5.6%	Loss of revenue	2,800	155			
			Northern/Southern gas pipeline perpendicular to project embankment at Mildred Island impacted due to land scour	1.6%	Repair	5,950	94			
				1.6%	Loss of revenue	0	0			

Probabilities of Breach Affecting Gas Pipelines

Scenario		Probabilities		Note
Critical length of reach for an outward breach	5,300	Prob of breach affecting individual gas pipeline at Mildred Island	43.8%	5,300' estimate from Appendix B
	5,100	Prob of breach affecting gas pipeline at Palm Tract	37.5%	5,100' estimate from Appendix B
Width (W) of on-land scour from an inward breach	600	Prob of breach affecting gas pipeline at Palm Tract	1.6%	
		Prob of breach affecting northern pipeline at Mildred Island	5.6%	3,000' is length of northern gas pipeline along the embankment to junction point; Critical reach = 3,000 + W +W
		Prob of breach affecting southern pipeline	1.6%	Critical reach of embankment = W + W

Table 15
Summary of Consequences of Breach Scenarios (1 of 2)

Loading Event, *i*	Operational Scenario, *k*	Breach Scenario, *m*	Repair Costs - Rock Berm Alternative ($000)	Repair Costs - Bench Alternative ($000)	Repair Costs - No Action ($000)	Cost of Fish Entrainment Recovery ($000)	Cost of Mitigation to Fish Impact ($000)	Cost of Making Up Water Supply ($000)	Cost of Repairs at Marinas ($000)	Expected Cost of Flooding of Islands ($000)	Expected Value of Loss of Life ($000)	Expected Loss due to Infra-structure Damage in Slough (RR, Aqueduct, Gas Pipelines) ($000)	Consequences of Given Breach Scenario - Rock Berm Alternative ($000), c_{ikm}	Consequences of Given Breach Scenario - Bench Alternative ($000), c_{ikm}	Consequences of Given Breach Scenario - No Action ($000), c_{ikm}
Webb Tract															
Flooding	1. Slough water level high (elevation +6.6' to 8'), reservoir empty (elevation –15')	One inward breach	28,214	28,214	25,800	10				48,851			**28,224**	**28,224**	**74,661**
		Two inward breaches	56,429	56,429	51,600	10				48,851			**56,439**	**56,439**	**100,461**
Seismic	1. Low tide (slough water level -1'), reservoir full (elevation	One outward breach	28,214	28,214	25,800		50		220		391		**28,875**	**28,875**	
		Two outward breaches	56,429	56,429	51,600		50		440		782		**57,701**	**57,701**	
	2. High tide (slough water level +3.5'), reservoir empty	One inward breach	28,214	28,214	25,800	10				48,851			**28,224**	**28,224**	**74,661**
		Two inward breaches	56,429	56,429	51,600	10				48,851			**56,439**	**56,439**	**100,461**
Operational	1. Low tide (slough water level -1'), reservoir full (elevation +4')	Outward breach on reach in front of **Bethel Island / Franks Tract**	28,214	28,214	25,800		50	12,600	0	0	391		**41,255**	**41,255**	
		Outward breach on reach in front of **Bradford Island**	28,214	28,214	25,800		50	12,600	0	21,578	391		**62,834**	**62,834**	
		Outward breach on reach in front of **Twitchell Island**	28,214	28,214	25,800		50	12,600	100	1,908	391		**43,263**	**43,263**	
		Outward breach on reach in front of **Brannan Island / Andrus Island**	28,214	28,214	25,800		50	12,600	100	14,839	391		**56,194**	**56,194**	
		Outward breach on reach in front of **Bouldin Island**	28,214	28,214	25,800		50	12,600	20	9,766	391		**51,041**	**51,041**	
		Outward breach on reach in front of **Venice Island**	28,214	28,214	25,800		50	12,600	0	5,310	391		**46,566**	**46,566**	
		Outward breach on reach in front of **Mandeville Island**	28,214	28,214	25,800		50	12,600	0	5,327	391		**46,582**	**46,582**	
	2. High tide (slough water level +3.5'), reservoir empty (elevation –15'), Low fresh water flow	One inward breach	28,214	28,214	25,800	10		15,750		48,851			**43,974**	**43,974**	**90,411**
	3. High tide (slough water level +3.5'), reservoir empty (elevation –15'), High fresh water flow	One inward breach	28,214	28,214	25,800	10				48,851			**28,224**	**28,224**	**74,661**

Table 15
Summary of Consequences of Breach Scenarios (2 of 2)

Bacon Island

Loading Event, *i*	Operational Scenario, *k*	Breach Scenario, *m*	Repair Costs - Rock Berm Alternative ($000)	Repair Costs - Bench Alternative ($000)	Repair Costs - No Action ($000)	Cost of Fish Entrainment Recovery ($000)	Cost of Mitigation to Fish Impact ($000)	Cost of Making Up Water Supply ($000)	Cost of Repairs at Marinas ($000)	Expected Cost of Flooding of Islands ($000)	Expected Value of Loss of Life ($000)	Expected Loss due to Infra-structure Damage in Slough (RR, Aqueduct, Gas / Liquid Pipelines) ($000)	Consequences of Given Breach Scenario - Rock Berm Alternative ($000), c_{ikm}	Consequences of Given Breach Scenario - Bench Alternative ($000), c_{ikm}	Consequences of Given Breach Scenario - No Action ($000), c_{ikm}
Flooding	1. Slough water level high (elevation +6.6' to 8'), reservoir empty (elevation –15')	One inward breach	28,214	28,214	25,800	10				80,395			**28,224**	**28,224**	**106,205**
		Two inward breaches	56,429	56,429	51,600	10				80,395			**56,439**	**56,439**	**132,005**
Seismic	1. Low tide (slough water level -1'), reservoir full (elevation	One outward breach	28,214	28,214	25,800		50		60		391		**28,715**	**28,715**	
		Two outward breaches	56,429	56,429	51,600		50		120		782		**57,381**	**57,381**	
	2. High tide (slough water level +3.5'), reservoir empty	One inward breach	28,214	28,214	25,800	10				80,395			**28,224**	**28,224**	**106,205**
		Two inward breaches	56,429	56,429	51,600	10				80,395			**56,439**	**56,439**	**132,005**
Operational	1. Low tide (slough water level -1'), reservoir full (elevation +4')	Outward breach on reach in front of **Woodward Island**	28,214	28,214	25,800		50	12,600	0	56,388	391	5,000	**102,643**	**102,643**	
		Outward breach on reach in front of **Orwood Tract**	28,214	28,214	25,800		50	12,600	20	16,643	391	24,180	**82,099**	**82,099**	
		Outward breach on reach in front of **Palm Tract**	28,214	28,214	25,800		50	12,600	0	30,681	391	1,836	**73,772**	**73,772**	
		Outward breach on reach in front of **Holland Tract**	28,214	28,214	25,800		50	12,600	20	34,852	391		**76,128**	**76,128**	
		Outward breach on reach in front of **Quimby Island**	28,214	28,214	25,800		50	12,600	0	0	391		**41,255**	**41,255**	
		Outward breach on reach in front of **Mandeville Island**	28,214	28,214	25,800		50	12,600	0	95,880	391		**137,135**	**137,135**	
		Outward breach on reach in front of **Mildred Island / McDonald Tract**	28,214	28,214	25,800		50	12,600	0	0	391	2,759	**44,015**	**44,015**	
		Outward breach on reach in front of **Lower Jones Tract**	28,214	28,214	25,800		50	12,600	20	24,179	391		**65,455**	**65,455**	
		Outward breach on reach in front of **Upper Jones Tract**	28,214	28,214	25,800		50	12,600	0	48,450	391	24,180	**113,885**	**113,885**	
	2. High tide (slough water level +3.5'), reservoir empty (elevation –15'), Low fresh water flow	One inward breach	28,214	28,214	25,800	10		15,750		80,395		505	**44,480**	**44,480**	**122,460**
	3. High tide (slough water level +3.5'), reservoir empty (elevation –15'), High fresh water flow	One inward breach	28,214	28,214	25,800	10				80,395		505	**28,730**	**28,730**	**106,710**

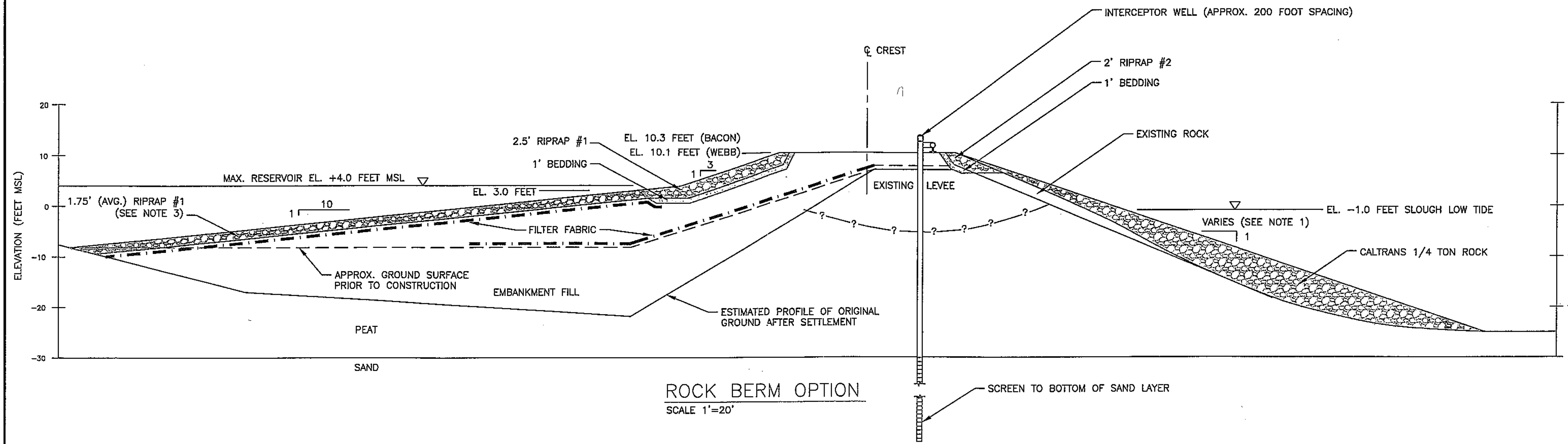
Table 16
Comparison of Risks under Re-Engineered Project Alternatives and Existing Levees

Reservoir Island	Annual Failure Probability			Expected Dollar Risk during 50 Years ($000)				Expected Number of Fatalities during 50 Years		
						Existing Levee				
	Rock Berm Alternative	Bench Alternative	Existing Levee	Rock Berm Alternative	Bench Alternative	excluding loss of resources on the Project Island	including loss of resources on the Project Island	Rock Berm Alternative	Bench Alternative	Existing Levee
Webb Tract	0.0107	0.0113	0.1120	18,625	19,613	170,352	299,452	0.0026	0.0064	Insignificant
Bacon Island	0.0109	0.0116	0.0820	18,962	20,196	119,005	342,909	0.0025	0.0073	Insignificant

Table 17
Risk Contributions of Loading Events

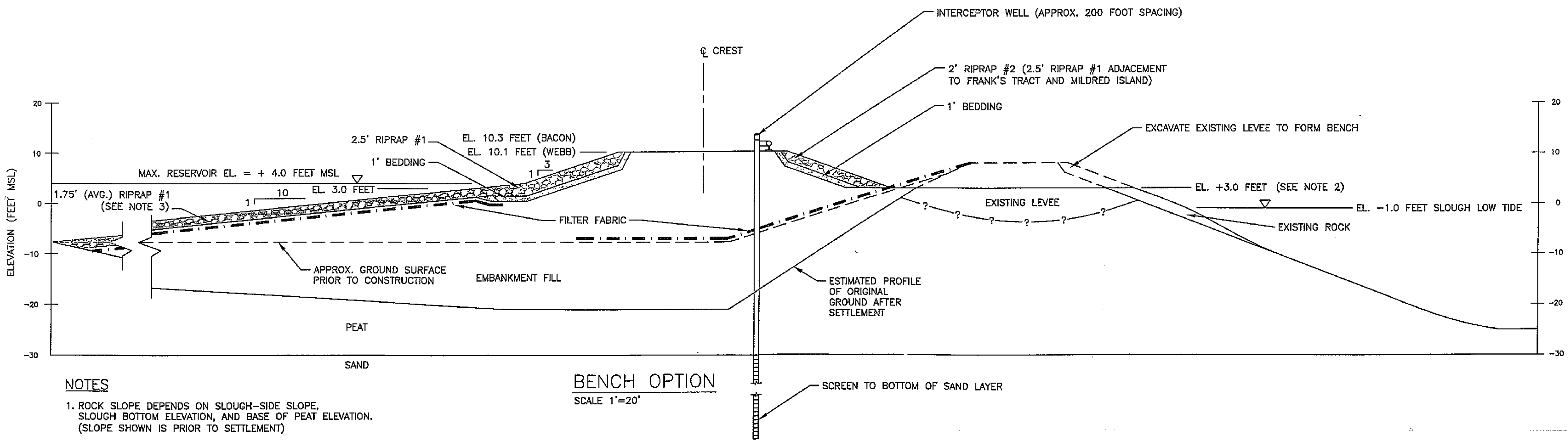
Reservoir Island	% Contribution to Annual Failure Probability			% Contribution to Expected Dollar Risk during 50 Years				% Contribution to Expected Number of Fatalities during 50 Years		
						Existing Levee				
	Rock Berm Alternative	Bench Alternative	Existing Levee	Rock Berm Alternative	Bench Alternative	excluding loss of resources on the Project Island	including loss of resources on the Project Island	Rock Berm Alternative	Bench Alternative	Existing Levee
Webb Tract										
-Flooding	42%	39%	48%	40%	38%	41%	44%	0%	0%	N/A
-Seismic	57%	60%	7%	59%	61%	8%	8%	98%	99%	
-Operational	1%	1%	45%	1%	1%	51%	48%	2%	1%	
-Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	
Bacon Island										
-Flooding	41%	38%	65%	39%	37%	59%	63%	0%	0%	N/A
-Seismic	58%	61%	10%	60%	62%	12%	11%	98%	99%	
-Operational	1%	1%	24%	1%	1%	30%	26%	2%	1%	
-Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	

Figures



ROCK BERM OPTION

SCALE 1'=20'



BENCH OPTION

SCALE 1'=20'

NOTES

1. ROCK SLOPE DEPENDS ON SLOUGH-SIDE SLOPE, SLOUGH BOTTOM ELEVATION, AND BASE OF PEAT ELEVATION. (SLOPE SHOWN IS PRIOR TO SETTLEMENT)
2. BENCH WIDTH VARIES FROM 31' TO 65' DEPENDING ON BASE OF PEAT ELEVATION.
3. RIPRAP TO BE PLACED ON NORTH AND WEST FACING SLOPES. 2' EARTH FILL COVER OVER FILTER FABRIC ON SOUTH AND EAST FACING SLOPES.

0 10' 20' 40'
SCALE: 1"= 20'

URS	Project No.26814886 IN-DELTA STORAGE PROGRAM	**TYPICAL EMBANKMENT SECTIONS CONCEPTUAL**	FIGURE 1

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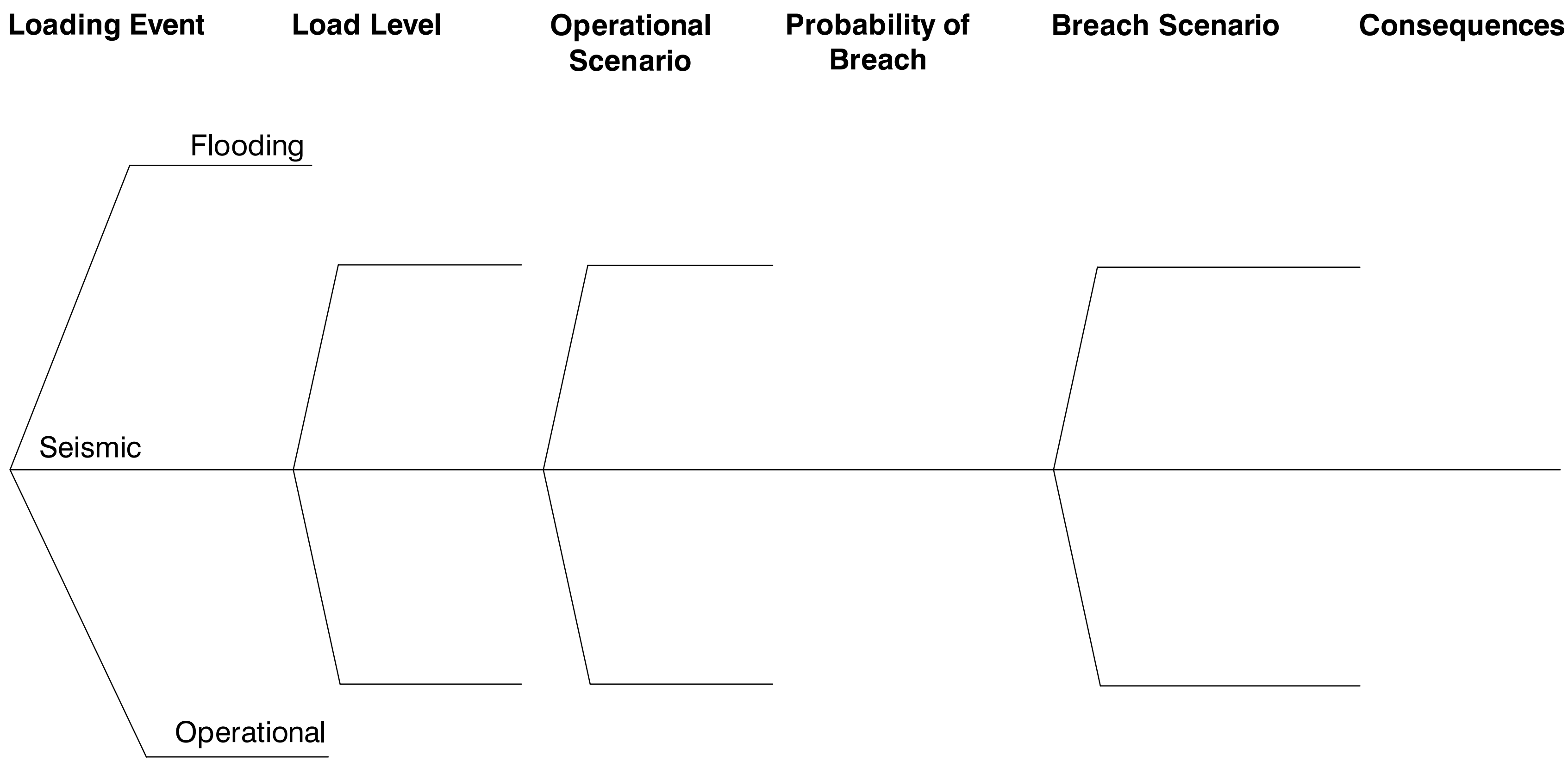

URS

Project No. 26814886

IN-DELTA
STORAGE PROGRAM

RISK ANALYSIS MODEL

FIGURE
2

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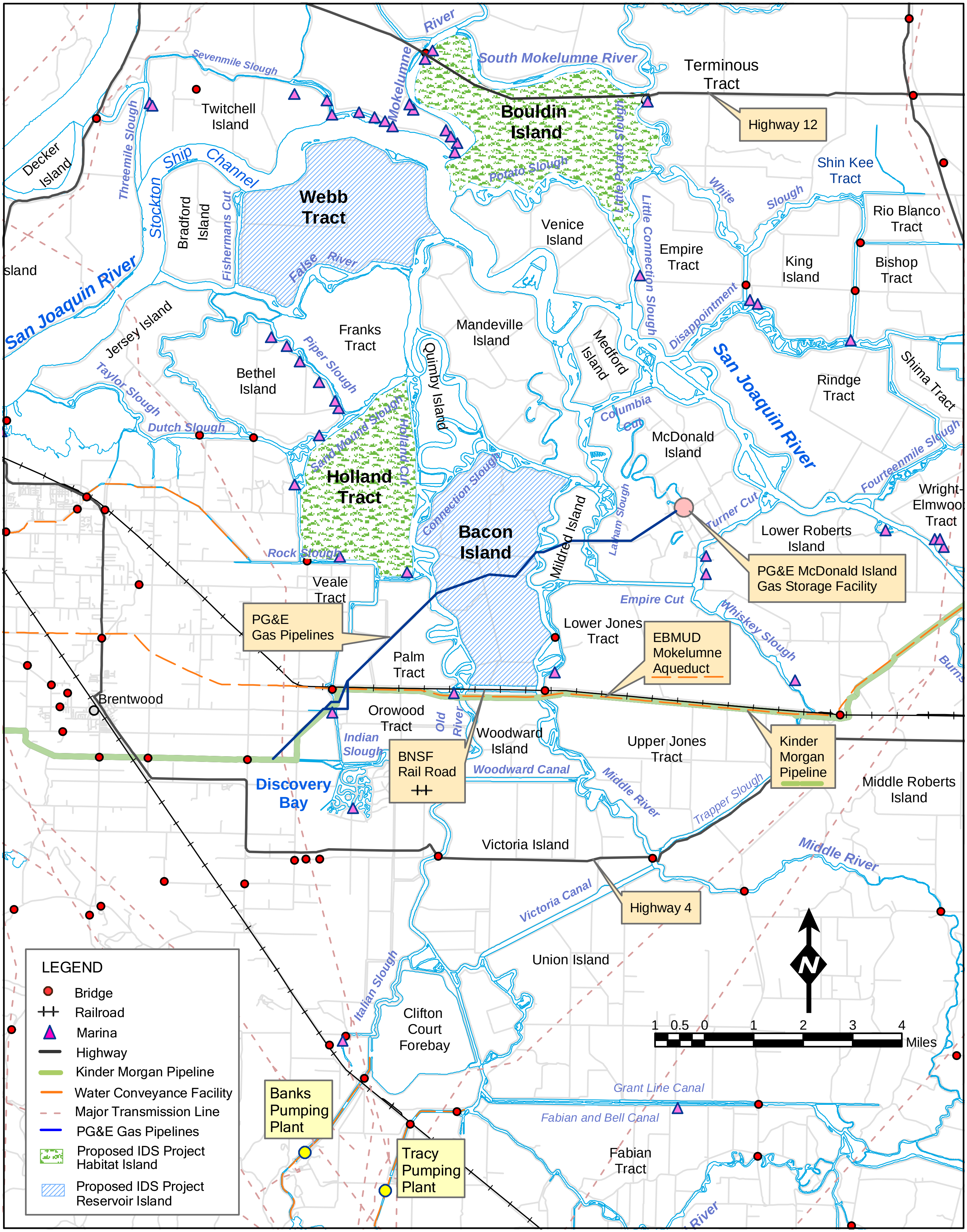

Figure 3. Existing Main Infrastructure

APPENDIX A

DATA SUMMARY FOR JUNE 3, 2004 UPPER JONES TRACT LEVEE FAILURE

BACKGROUND AND PURPOSE

On June 3, 2004, a levee break occurred in the west levee of the Upper Jones Tract in the southern region of the Delta in San Joaquin County. The break caused flooding of the Upper Jones Tract and subsequently, the Lower Jones Tract, and resulted in substantial damage and economic losses. Photographs of the Jones Tract levee failure from DWR are included at the end of this appendix.

The risk analysis described in this report includes a scenario involving a levee break on a neighboring island to one of the project islands and consequences of flooding that might result from a break similar to the one that occurred in Upper Jones Tract on June 3, 2004. The data from the June 3, 2004 levee break, therefore, was used to calibrate and validate the assumptions made in the risk analysis regarding the consequences of flooding a neighboring island in Section 3.3 of this report. DWR and URS staff reviewed and compiled available data from the June 3, 2004 event regarding emergency response and repair costs and relevant economic losses. The relevance and use of these data for the present risk analysis are noted where applicable in Section 3 of the report.

HISTORY OF EVENT[1]

On June 3, 2004, at approximately 7:50 a.m. a levee breach occurred on the west levee of the Upper Jones Tract in the southern region of the Delta in San Joaquin County. As the flooding began, State, federal and local agencies began mobilizing.

By 9:00 a.m., the State Federal Flood Operations Center had activated, implemented the “Delta Levee Failure Incident” response protocol, and begun coordinating with numerous State, federal and local agencies.

The San Joaquin Sheriffs Office established a command post on the eastern side of Upper Jones Tract adjacent to State Highway 4.

Evacuation of Upper Jones Tract and Lower Jones Tract began. DWR and other agencies determined that the Trapper Slough levee on the southern border of Upper Jones Tract was not at a high enough elevation to protect State Highway 4.

DWR established the following objectives for protecting lives and property:

- Protect Highway 4 from failure by Trapper Slough
- Prevent the failure of Jones Tract perimeter levees and adjacent levee islands
- Close the levee breach
- Minimize saltwater intrusion into the Delta

[1] From Department of Water Resources, Division of Flood Management, After Action Report, 2004 Jones Tract Incident, Memorandum Report, December 2004.

DWR and the U.S. Bureau of Reclamation (USBR) immediately took steps to try to protect water quality by restricting the flow of water exported south from their respective pumping plants and by releasing water from upstream reservoirs.

By the evening of June 4, 2004 an emergency request under Public Law 84-99 was made to the U.S. Army Corps of Engineers (Corps) to raise and armor the Trapper Slough Levee to protect State Highway 4 and to close the breach. Ultimately the Corps agreed to raise the Trapper Slough levee (with assistance from the California Department of Transportation (Caltrans) and materials provided by DWR), but denied the request for armoring the Trapper Slough levee and the closing of the breach. Governor Arnold Schwarzenegger declared a State of Emergency.

On June 5, 2004 a Unified Command had been established at the site of the Sheriff's command post. Sharing the command were staff from San Joaquin County, DWR, and Caltrans. Governor Arnold Schwarzenegger visited the flooded island. That same day an agreement was reached with Dutra Construction to close the breach.

On June 6, 2004 DWR established a command post at the site of the Unified Command and on June 8, 2004 took over control of the incident.

Raising of the Trapper Slough levee was completed on June 8, 2004 and, at the request of the Reclamation Districts 2038 and 2039, DWR began a flood fight to protect the island interior levees. Approximately 16 miles of levee were eventually lined with visquine or armored with rock to protect the inside of the island. California Department of Forestry (CDF) and California Conservation Corps (CCC) crews were deployed to carry out the flood fight to protect the island's interior.

Both the breach closure and protection of the interior levee slopes were completed on June 30, 2004. As a result there were no further problems due to high tides or winds.

On June 24, 2004 DWR awarded a contract for the dewatering of the island, and on July 12, 2004 operation of four 42-inch pumps began at a pump station constructed on Upper Jones Tract. By July 26th construction of another pump station was completed north of the Burlington Northern – Santa Fe Railroad (BNSF) line, and all 10 pumps (eight 42-inch and two 30-inch) were in operation. The maximum flow rate was approximately 350,000 gallons per minute (780 cubic feet per second).

On June 30, 2004 a Presidential Declaration of Emergency was declared which authorized the Federal Emergency Management Agency (FEMA) to reimburse the costs of responding to this emergency.

On July 12, 2004 the incident was officially closed by OES. Pumpout of the island and monitoring for potential future failures continued. As of December 14, 2004, dewatering of the Upper Jones Tract was essentially finished but pumping was expected to continue for a couple of days at Lower Jones Tract. An estimated 140,000 acre-feet of water had been removed from the island. The remaining water in drainage ditches and low-lying areas will be pumped by Reclamation District's pumps.

SUMMARY OF FLOOD DAMAGE/REPAIR/LOSS ESTIMATES

DWR and URS staff contacted a number of agencies and companies involved in emergency response and repair work following the levee breach and compiled data on cost of various response and repair actions, and economic losses. Table A-1 provides a summary of costs and losses and the sources of information.

In addition to the dollar impacts, some other aspects of the levee break and subsequent flooding relevant to the risk analysis are discussed below.

Impact to Water Quality and Water Supply

Within two hours of the notification of the levee break, Central Valley Project (CVP) and State Water Project (SWP) operators took actions to minimize likely salinity intrusion into the Central Delta as a result of Jones Tract inundation. Specifically, they reduced exports to minimal levels, and in consultation with other agencies, opened the Delta Cross Channel gates. With the reduction in exports, the Project Operators solicited voluntary demand reductions from their contractors to alleviate the sudden pressures put on supplies from San Luis Reservoir. The demand reductions continued from five to seven days while the Project staff evaluated salinity intrusion and planned a continual course of action. The export reduction was estimated to be about 30,000 acre-feet. During this time, the salinity levels in the Western Delta increased. However, after June 19, the salinity levels decreased and remained below the original Below Normal Year standards throughout the control period and no benefits or adverse impacts occurred to any legal user of water, fish, wildlife, or other in-stream beneficial use.

Information provided by CCWD suggested that there were no violations in water quality standards at their Rock Slough and Los Vaqueros intakes on Old River due to the Jones Tract flooding and no additional treatment costs were incurred.

Impact to Fishery

The Jones Tract levee failure occurred in close proximity to one of the major spawning areas for striped bass, but after the primary spawning period. Similarly, the seasonal emigration of juvenile salmon through the Delta was largely complete by the date of the levee failure. At the time of the failure, the centers of distribution for the 2004 cohorts of delta smelt and striped bass were several miles northwest of Jones Tract near the confluence of the Sacramento and San Joaquin rivers. Measures of direct loss derived from near-field larval and juvenile fish densities and the volume of water flooding Jones Tract suggest that roughly 1.5 million striped bass and 100,000 delta smelt were lost directly to the flooding, a small proportion of the cohort for both species. The failure resulted in alterations of planned water export operations that likely had a small positive effect on direct fish losses.

Table A-1						
June 3, 2004 Jones Tract Flood Damage/Repair/Loss Estimates						
Item		**Amount**	**Source**		**Notes**	
1. Emergency Response & Damage Repair						
	City of Stockton	30,700	5			
	Mosquito & Vector Control	29,500	2			
	San Joaquin County	1,531,957	2,3,4			
	CalTrans	1,188,738	5			
	USACE	400,000	12		1	
	CHP	202,053	5			
	CCC	516,000	9		2	
	CDF	1,331,000	9		3	
	OES	55,000	5			
	Dept of Toxics & Subs Control	55,400	5			
	DWR		9			
	Breach Closure	8,050,000	9		4	
	Contract with Granite Construction	500,000	9		5	
	Contract with Ford Construction	1,800,000	9		6	
	Pumpout	5,700,000	9		7	
	DWR Force Account Labor	1,342,000	9		8	
	DWR Subtotal	17,392,000	9		9	
	McDonald Island (RD 2030)	80,670	5			
	Lower Jones (RD 2038)	10,595,588	5			
	Upper Jones (RD 2039)	5,820,954	5,6			
	Victoria Island (RD 2040)	196,250	5			
	Woodward Island (RD 2072)	56,349	5			
	Lower Roberts (RD 684)	61,450	5			
	Drexler Tract	0	2,6			
	Union Island (RD 2)	0	2,7			
	Bacon Island (RD 2038)	0	2,8			
	Subtotal	**39,543,609**				
2. Individual Assistance						
	Primary Residence	8,000,000	2			
	Business	239,942	2			

	Other	5,000,000	2			
	Subtotal	**13,239,942**				
3. Agricultural Damage						
	Crops/grazing Land	17,666,829	1,2			
	Farm Buildings and Machinery	14,070,000	2			
	Livestock	300	2			
	Sub Total	**31,737,129**				
4. Infrastructure						
	EBMUD	10,568,000	5			
	BNSF Railroad Repair Cost	8,000,000	10			
	BNSF Railroad Revenue Loss	15,000,000	11			
	Subtotal	**33,568,000**				
5. Water Supply Project Operations						
	DWR	n/a	13		10	
	USBR	n/a	14		11	
	Subtotal	**0**				
Total		**118,088,680**				
Notes						
1	The money came from the federal government, not from CA OES, and the funds were mostly used for flood fighting purposes.					
2	Costs updated by Terry Lewis after original OES estimate of $32,199					
3	Costs updated by Terry Lewis after original OES estimate of $1,161,020					
4	None					
5	Various support activities					
6	Rock slope protection on interior levees					
7	Includes additional OES $1.2M request based on info provided by DWR					
8	DWR employees + All flood fight related expenses + Small Contracts to obtain materials and supplies + Control Center + Includes an additional $200,000 for Replacement of Supplies.					
9	Costs updated by Terry Lewis after original OES estimate of $16,716,822					
10	12-22-04 email to Amy Bindra from John Leahigh: Earlier statement, "benefit of pumpout operation negating impacts to on CVP and SWP for making releases for additional delta outflow in June", has not been confirmed. A study to confirm this statement has not been made, but the availability of resources to run such a study is being looked into.					

11	12-22-04 phone conversation with USBR's Valerie Ungvari.					
	Source/Contacts:	**Telephone**	**Date Information Obtained**			
	1. Tom Reed, SJC Ag Office	Tel: 209 838 2276	December 1, 2004			
	2. Michael Cockrell, SJC OES	Tel: 209 468 3967	December 9, 2004			
	3. Tom Caldwell:SJC Maint. Dept	Tel: 209 468 3074	December 13, 2004			
	4. Tom Casillas: SJC Maint. Dept	Tel: 209 468 3074	December 2, 2004			
	5. Doug Lashmett, CA OES	Tel: 916 845 8225	December 13, 2004			
	6. Bill Darcie, Drexler Tract	Tel: 209 810 2708	December 21, 2004			
	7. Pam Hoslett, Union Island	Tel: 209 943 5551	December 16, 2004			
	8. Pam Hoslett, Bacon Island (RD 2038)	Tel: 209 943 5551	December 16, 2004			
	9. Terry Lewis, DWR, DOFM	Tel: 916 574 0644	December 21, 2004			
	10.John Fleming, BNSF Stockton	Tel: 209 460 6175	November 15, 2004			
	11.Russ Shelton, BNSF, Los Angeles	Tel: 323 267 4106	December 3, 2004			
	12.Larry, USACE, Emergency Response Mission	Tel: 916 557 6919	December 23, 2004			
	13.John Leahigh, DWR, SWP Operations Control Office	Tel: 916 574 2666	December 22, 2004			
	11.Valerie Ungvari, USBR, Water Operations Division	Tel: 916 979 2448	December 22, 2004			
	Paul Fujitani, USBR, Chief, Water Operations Division	Tel: 916 979 2199	December 22, 2004			

Floodwater enters island, 6/4

Expanding floodwater, 6/4

Railroad trestle separating Upper and Lower Jones Tract, 6/4

Railroad trestle damaged, 6/6

Mokelumne Aqueduct parallels railroad

Trapper Slough levee raised 6 feet

Rock is placed at levee ends

Placing plastic to control erosion (file photo)

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APPENDIX B

HYDRAULIC ANALYSIS AND RESULTS

1. Calculation of Peak Velocities for Selected Breach Scenarios

Based on embankment breach analyses results presented in Flooding Analysis report (URS, June 2003), we have estimated approximate peak flow velocities on adjacent levees for hypothetical breach scenarios. The selected breach scenarios / locations are shown in Figures 1 and 2 and are described in Table 1.

Table 1 presents the estimated peak velocities for the selected "outward" breach scenarios of Bacon Island. For these outward breach scenarios, the peak velocities were estimated assuming a hydraulic head difference of 5 feet across the reservoir embankment (i.e. reservoir water level = + 4.0 feet and slough water level = –1.0 feet). (See URS, June 2003.)

Table 1. Peak Velocities for Outward Breach Scenarios on Bacon Island

Breach Scenario & Location on Bacon Island	Slough Width (feet)	Peak Velocity (feet/sec)	Description of Adjacent Structure / Remarks
1. At Southern Levee(1)			
Line 1A	290	14.4	BNSF RR embankment
Line 1B	205	10.7	Woodward Island
2. At South-Eastern Edge(1)			
Line 2	375	13.1	RR bridge abutment (Middle R)
Line 3	1080	9.0	Jones Tract
3. At South-Western Edge(1)			
Line 4	415	12.6	RR bridge abutment (Old R)
Line 5	1375	8.2	Orwood Tract
4. At PG&E Gas Line(2)			
Line 6	460	12.2	Mildred Island
Line 7	540	11.5	Palm Tract

(1). See Figure 1 for Mokelumne aqueduct and BNSF railroad bridge crossings
(2). See Figure 2 for PG&E Gas pipeline crossings.

We have also calculated the maximum slough widths that provide a threshold velocity of 8 feet/sec (see URS, June 2003) on the adjacent levee for both outward and inward breach scenarios as 1500 ft and 340 feet, respectively.

Table 2 presents the estimated peak velocity for the "inward" breach on southern levee of Bacon Island (at Line 1A) in which the slough width is less than 340 feet. The peak velocity for this inward scenario was estimated assuming a hydraulic head difference of 15 feet across the reservoir embankment (i.e. reservoir water level = -8.0 feet and slough water level = +7.0 feet). (See URS, June 2003.)

Table 2. Peak Velocity for Inward Breach on Southern Levee of Bacon Island

Breach Scenario & Location on Bacon Island	Slough Width (feet)	Peak Velocity (feet/sec)	Description of Adjacent Structure / Remarks
1. At Southern Levee			
Line 1A	290	9.1	BNSF RR embankment

2. Calculation of Scour Depths for Impacted Areas and Resources

Scour depths at Mokelumne aqueduct, BNSF railroad bridge crossings, and PG&E gas pipeline crossings were estimated to determine potential risks associated with the outward breach scenarios (see Scenarios 2, 3, and 4 in Table 1). Table 3 presents approximate scour depths estimated based on Neil's Competent/Limiting Velocity Control method (USBR 1982). This method uses both hydraulic parameters (including average flow depths and velocities) and bed material sizes to calculate scour depths.

Table 3. Scour Depths for Impacted Areas and Resources

Scour /Location	Estimated Scour Depth (ft)	Aqueduct Burial Depth (ft)	Remarks
1. Mokelumne Aqueducts:			
Aqueduct crossing at Middle River	11.3	20 (Aqueduct #3) 5 (Aqueduct #2) 5 (Aqueduct #1)	5 ft backfill w/ rock cover(1) Placed on timber piles(1) Placed on timber piles(1)
Aqueduct crossing at Old River	9.0	20 (Aqueduct #3) 5 (Aqueduct #2) 5 (Aqueduct #1)	Backfill with rock cover(1) Placed on timber piles(1) Placed on timber piles(1)
2. BNSF RR Bridges:			
Bridge abutment at Middle River	23.3	Not available	Placed on timber piles(2)
Bridge abutment at Old River	21.9	Not available	Placed on timber piles(2)
3. PG&E Gas Pipelines:			
Pipeline crossing at Middle River	20.7	?	?
Pipeline crossing at Old River	18.7	?	?

(1). Source: Mokelumne Aqueduct Seismic Upgrade Project (EMBUD, 1996)
(2). Personal contact: Bob Grimes (BNSF Railway) and Mike Forrest (URS) on May 05, 2004.

3. Maximum Critical Length of the Project Embankment

Maximum critical length(s) of the project embankment on Bacon Island in front of Woodward Island such that an outward breach on this critical length would cause a failure of Mokelumn aqueduct were estimated be as (see Figure 1):

- 1, 750 feet (at southeast corner of Bacon Island)
- 750 feet (at southwest corner of Bacon Island)

These estimates was made based on physical characteristics of the adjacent water-bodies (including sloughs and wetlands) and the estimate of maximum slough width (1500 ft) that provide a threshold velocity of 8 feet/sec on an adjacent levees during an outward breach.

Similarly, maximum critical lengths of the project embankment on Bacon Island near the PG&E pipeline crossings at Middle River and Old River (see Figure 2) were estimated as 5300 feet and 5100 feet, respectively.

4. Assumptions and Limitations

- Detailed hydraulic analyses were not performed using the RMA-2 model to estimate peak velocities for the slough widths presented in Tables 1 and 2. Estimates of peak velocities in Tables 1 and 2 were based on embankment breach analyses results presented in Flooding Analysis reports (URS, June 2003) for three typical slough widths.

- Availability of site specific data on slough cross-sections and bed material sizes were limited for the scour analysis. Therefore, the following approximate values were used for the local scour depth estimates:

  - Average flow depth at the crossing is about 15 feet
  - Mean grain size (D_{50}) for soil type SM / ML is about 0.07 mm

- For railroad bridge crossings, no detailed scour analyses were performed to calculate total scour depths (long-term + contraction + local) using the HEC-RAS and HEC-18 models.

FIGURE 1

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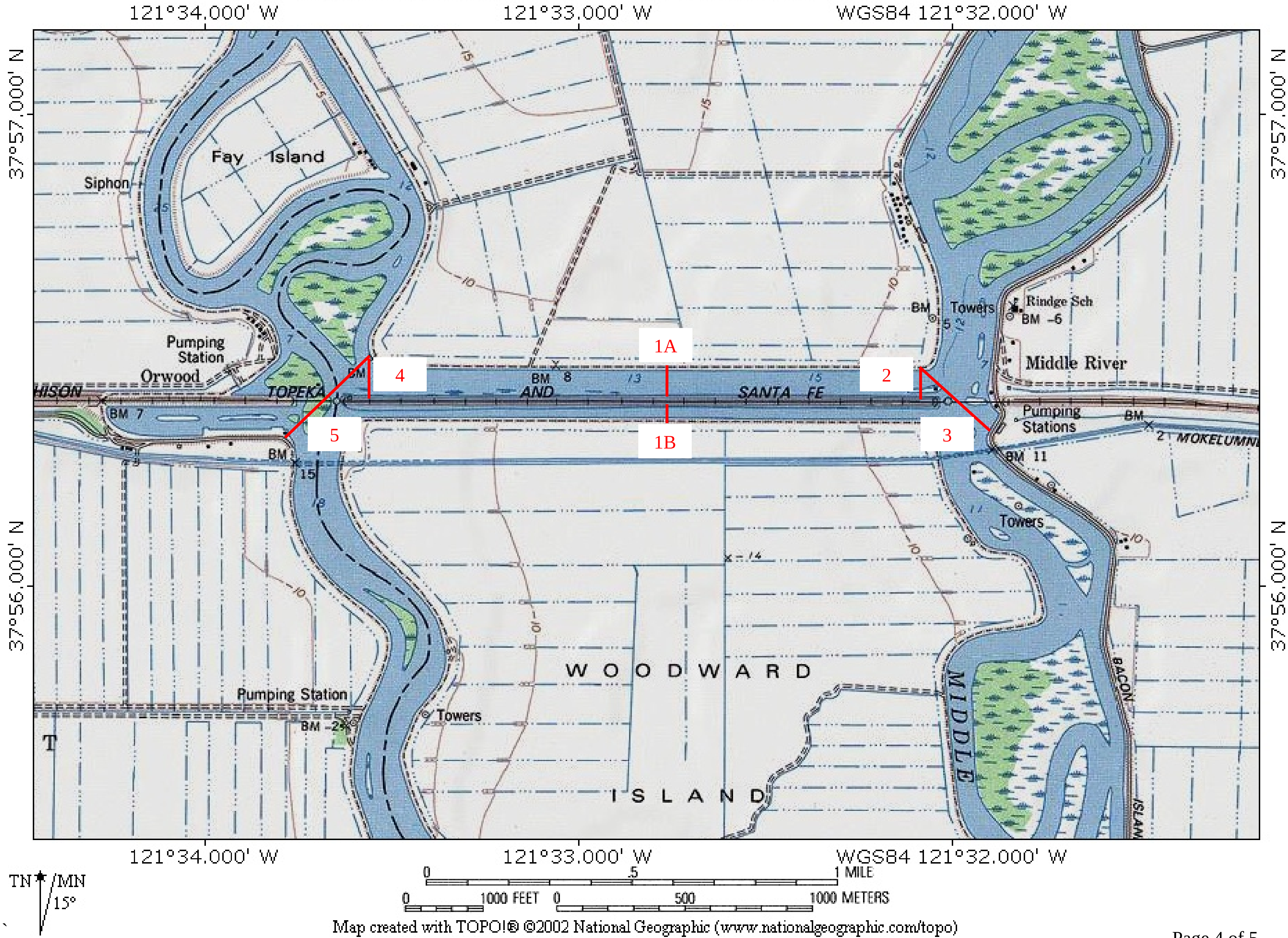

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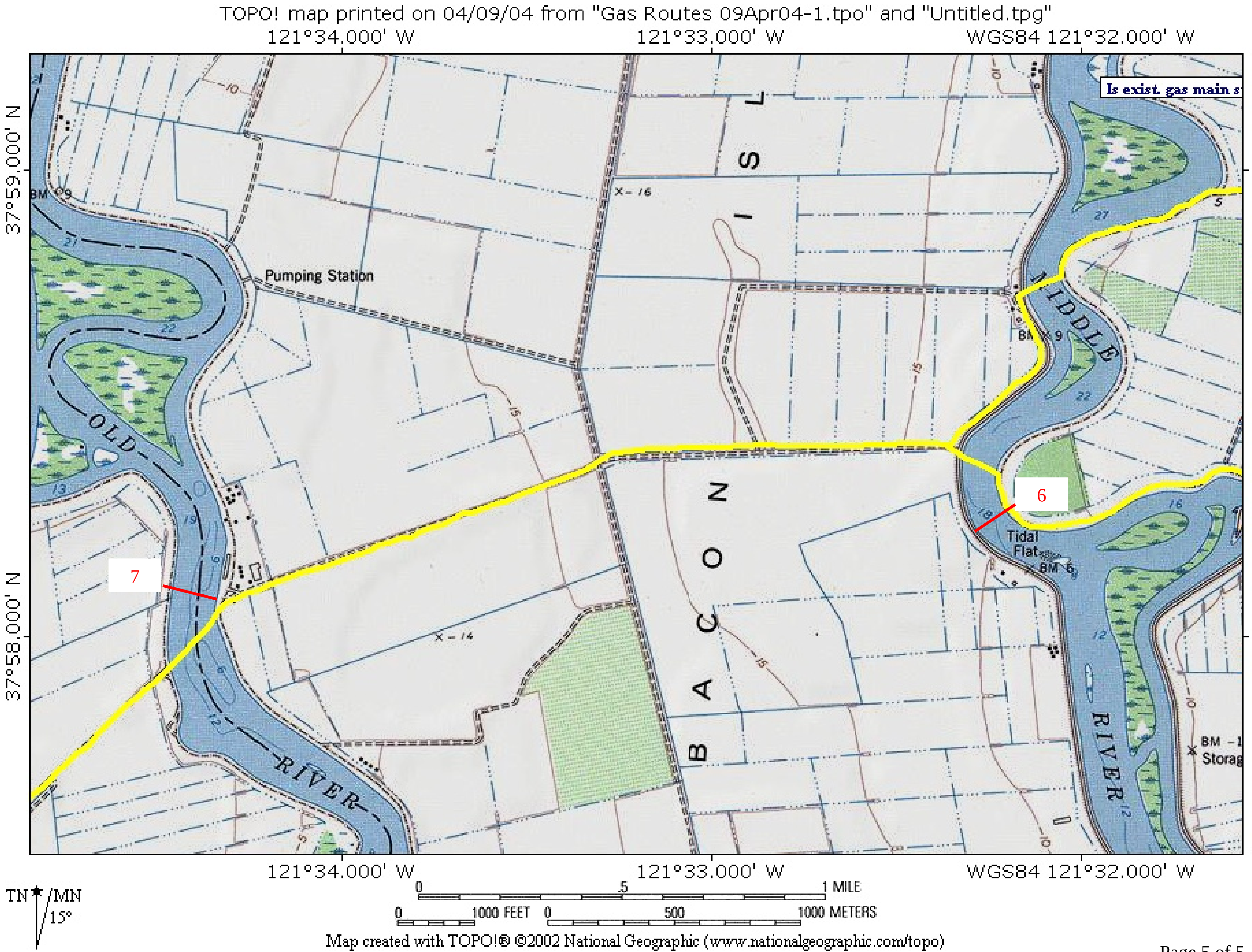
FIGURE 2



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